IN NOVA SCOTIA 1982 83

OIL AND GAS EXPLORATION IN NOVA SCOTIA 1982 83

Nova Scotia
Department of Mines and Energy

Honourable Ronald Barkhouse, Minister
John J. Laffin, P. Eng., Deputy Minister

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FRONT COVER RIGHT
"SDS Vinland". Semi-submersible drilling rig presently operated by Shell Canada Resources Ltd. drilling Uniacke G-72. Photo courtesy SDS Drilling.

FRONT COVER LEFT
Representative onshore drilling rig.

BACK COVER
The Joseph Howe Building in which the Department of Mines and Energy is located.

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PREFACE

The energy situation in Nova Scotia and in Atlantic Canada in general is unique in Canada. The country as a whole has substantial energy resources in the form of oil, natural gas, coal, hydroelectricity, and uranium; crude oil accounts for only about 40 per cent of the Canadian energy demand. In contrast, crude oil imported to Nova Scotia dominates the province's energy mix; in 1982 it supplied slightly more than 70 per cent of its primary energy demand.

This produces important differences in various sectors of the economy. In 1982, oil accounted for less than 5 per cent of the electricity generated nationally and for approximately 38 per cent of the electricity generated in Nova Scotia. Furthermore, in Nova Scotia residential, commercial, and industrial space heating and industrial process heating were almost 100 per cent dependent on imported oil. This is in sharp contrast to the situation in Central and Western Canada which have access to secure domestic natural gas, oil and hydro electricity.

This high dependence on oil produces disproportionately high energy costs in Nova Scotia. The Atlantic region is also likely to suffer more than the rest of Canada should an unexpected disruption occur in the supply of imported oil since the region does not have ready access to domestically produced oil.

To correct this situation, Nova Scotia has initiated major programs in energy conservation, oil substitution, and emergency preparation. Conservation measures allow us to use our energy resources more efficiently, reduce operating costs, and extend the life of these non-renewable energy resources. Oil substitution measures permit us to diversify our energy mix by developing our indigenous energy resources and by obtaining access to resources available from other Canadian provinces. This diversification will eventually involve coal, offshore oil and gas, tidal power, and other renewable energy resources.

The world oil situation presents difficulties for Nova Scotia but it also provides opportunities for important economic gains. One of the most exciting turning points in the development of oil and gas off our shores was the signing on March 2, 1982 of the Canada-Nova Scotia Agreement on Offshore Oil and Gas Resource Management and Revenue Sharing. This agreement established a framework within which companies can plan and develop their exploration and development programs. As a result, exploration activity offshore has greatly increased and plans are underway to develop the Venture gas field off Sable Island.

INTRODUCTION

Following the large discovery of oil in Leduc, Alberta, in 1947, petroleum exploration intensified in western Canada. In the late fifties, industry broadened its search for petroleum to new areas and the continental shelf off Nova Scotia (Scotian Shelf) came to be considered an exciting prospect. In 1959, Mobil Oil undertook an air magnetometer survey of the Sable Island area. The following year, the company carried out its first seismic program and acquired approximately 1000 km of data on and around the Sable Island area. In 1963, Shell Canada licensed approximately 8.1 million hectares from the province. By early 1965, some 14.4 million hectares on the Scotian Shelf were licensed to other companies. During the early part of the 1970s, the area under license extended onto the slope, where water depths are greater than 200 m.

The area currently held by oil companies offshore Nova Scotia exceeds 15.0 million hectares; of this, 4.7 million hectares are under moratorium due to international boundary disputes. Some 2.2 million hectares are held under provincial license onshore Nova Scotia and in the Bay of Fundy.

In the offshore area, exploratory drilling started in 1967 with the Mobil C-67 well on Sable Island. This was followed in September 1969 by Shell Canada Limited, which contracted the semi-submersible drilling unit, Sedneth 1, to drill on the Scotian Shelf. By the end of July 1983, 81 wells had been drilled in our offshore area by a number of companies including Chevron, Mobil, Murphy, Petro-Canada, Shell and Union. Recently Husky/Bow Valley and Home Oil became new players offshore. Of the 81 wells drilled offshore, 12 are classified as significant discoveries including two recent wells drilled on the Olympia and South Venture structures. As of August 1983, five semi-submersible drilling units and two jack-up rigs were actively drilling offshore Nova Scotia. Of these, five were drilling wildcat wells and two were drilling appraisal wells (Venture B-52 and Venture H-22). The Venture wells will be valuable in delineating the extent of the Venture gas field and will, therefore, yield important data for appraising the reserves in the Venture Structure. Several companies were also actively shooting seismic programs over their offshore licenses in 1983.

Onshore, approximately 20 wells have been drilled for petroleum during the past 25 years by companies such as Anschutz, Chevron/Irving, Gulf, Imperial Oil and Murphy. During the past year, interest in the major basins of Nova Scotia increased with work programs involving mapping, seismic acquisition, and sample analysis. In the early part of 1983, Chevron shot a seismic program in the Lake Ainslie area on Cape Breton Island. Other companies have been looking with interest in the Minas Basin, Cumberland Basin and several other areas in Cape Breton.

Part I

OIL AND GAS EXPLORATION AND DEVELOPMENT

Roughnecks spinning chain; making a connection on an offshore drilling rig. Photo courtesy Bill Wilson, Mobil Oil.

A. Offshore

1. Geological Setting

The offshore areas of Nova Scotia having thicknesses of sediments capable of producing hydrocarbons are very extensive and surround the province. On the Scotian Shelf, potential sediments extend seaward over 320 km. Drilling to date has indicated sediments younger in age and much more widespread than those encountered onshore.

All of the 15.0 million hectares now held under offshore licenses have sediments favourable for the trapping of petroleum. Generally, the Scotian Shelf area contains thick sequences of mudstone, sandstone, shale, chalk and limestone that vary in thickness and depositional characteristics (see Figure 1 for representative microfossils on Scotian Shelf). Geophysical surveys indicate that the Sable Island sub-basin (Figure 2) may contain a thickness of sediment of up to 12 000 m. The deepest hole to date on the Scotian Shelf is Petro-Canada S.W. Banquereau F-34 that bottomed in shale at 6309 m.

The oldest mapped sedimentary rocks on the Scotian Shelf are evaporites, thought to be Upper Triassic in age. The sedimentary section comprises a seaward thickening wedge of Jurassic to Tertiary sediments. Initial sediments, overlying a pre-Carboniferous basement of Devonian granites and Cambro-Ordovician meta-sediments, are continental clastics, evaporites and dolomites characterizing the prerift and rifting sequences. These are followed by a major Jurassic transgression with the deposition of open-marine carbonates and their clastic equivalents. The Late Jurassic and Lower Cretaceous (Figure 3) is characterized by a regressive wedge of deltaic clastics built up along the continental shelf and slope, within which are transgressive and regressive cycles.

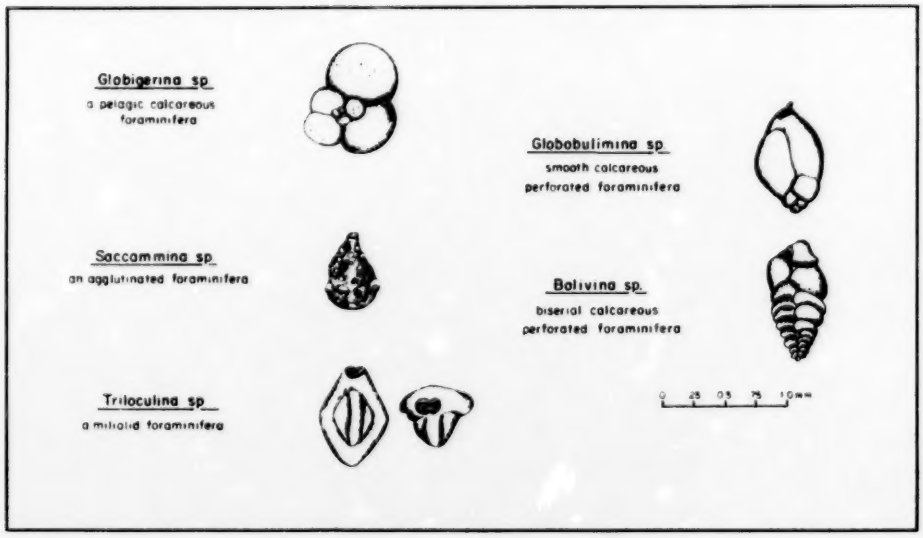


Figure 1. Representative microfossils from the Scotian Shelf

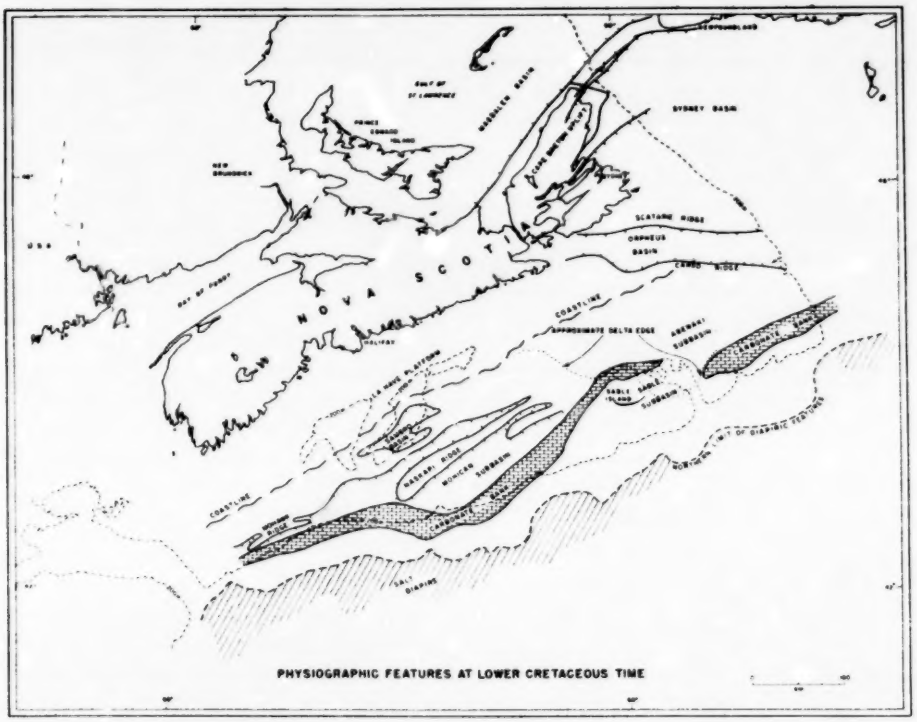


Figure 2. Physiographic features at Lower Cretaceous time

The Jurassic and early Cretaceous section is of prime interest in assessing the hydrocarbon potential of the Scotian Shelf. This section includes the shelf margin and the Baccaro carbonate front, which extends along the entire Scotian Shelf. In the back reef position to this carbonate, there is a predominately clastic section with some interbedded carbonates called the Mic Mac Formation. This section extends from the shelfward hingeline of the prerift salt basin to the Baccaro carbonate front. In the vicinity of Sable Island, the depocentre and focus of maximum sedimentation on the Scotian Shelf, the clastic influx passed over and through the reef complex to deposit clastics in front of the Baccaro carbonate.

Throughout the remaining Cretaceous time, a coarse clastic section known as the Missisauga Formation was deposited over the shelf and across the older Baccaro carbonate. Seaward of the reef, the coarse sands become more interbedded with shale and pass finally to shale.

In late Cretaceous time, a widespread chalk formation was deposited and overlain by the seaward prograding Tertiary clastics. An unconsolidated to consolidated sequence of mud and sand, mapped as recent, forms the remainder of the column.

The Abenaki and Sable sub-basins (Figure 2) form an important re-entrant into the regional shelf trend and a centre of maximum deposition that is critical to the generation of oil and gas.

The structures tested so far are either salt diapirs, such as the original Mobil oil and gas discovery on Sable Island, or down to basin fault structures, such as the Venture discovery. The hydrocarbons found to date

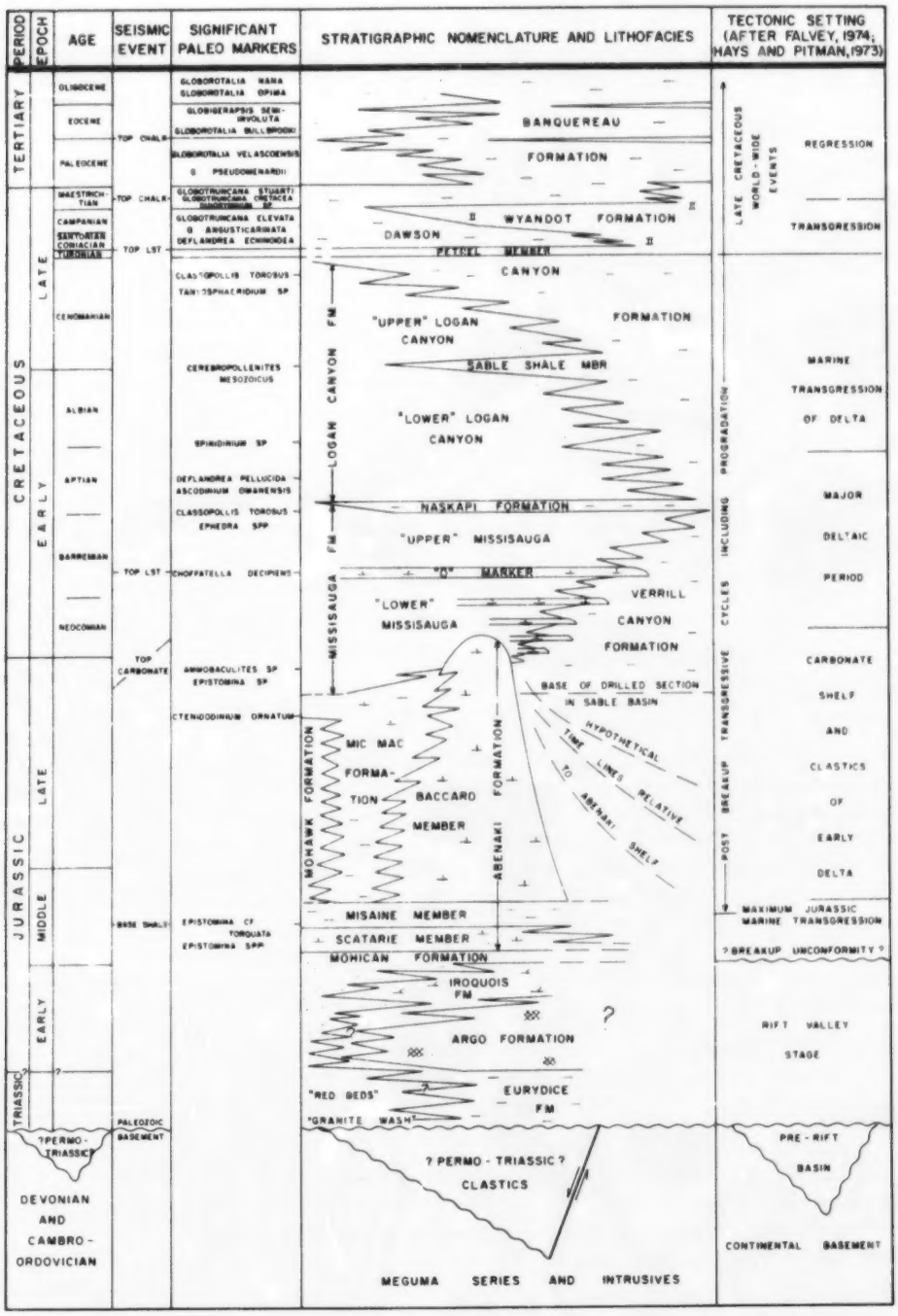
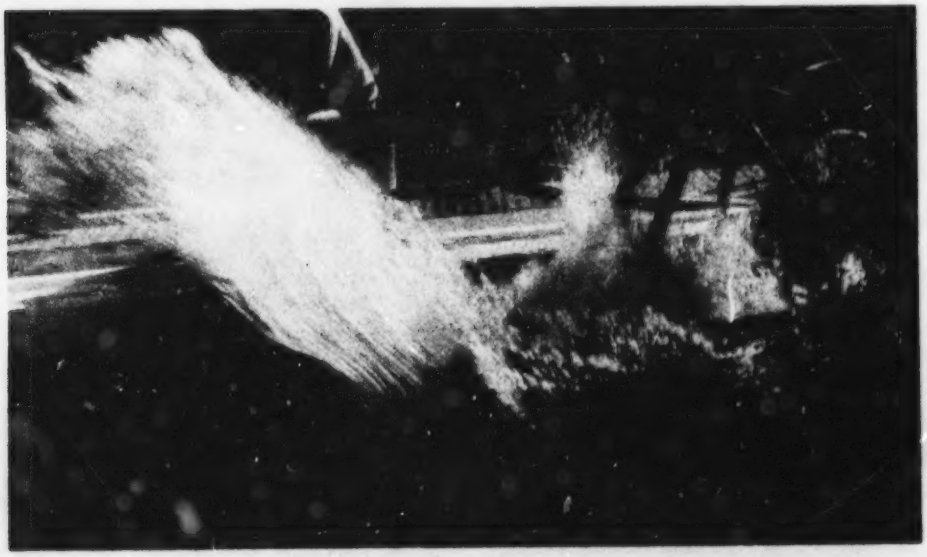


Figure 3. Stratigraphic diagram for the lithologic units present on the Nova Scotia Shelf

are essentially confined to the centre of maximum deposition which extends through the Abenaki and Sable sub-basins.

Hydrocarbons have been found in reservoirs ranging from Late Cretaceous to Upper Jurassicin age. Exploration has been frustrated because, in many cases, the hydrocarbons have been found in thin individual pay sands with each zone overlying water. As a result, a slight loss of elevation in a follow-up well has resulted in loss of the entire oil and gas pay. Alternately, the sand distribution has been erratic and pay sands present in a discovery have been absent in follow-up wells. The piercement salt domes have proven to be faulted and the hydrocarbon distribution has been complex as a result. The most consistent and, so far most successful, exploration play has been along the basin fault structural trend that extends through the Sable Basin where the fault structures lie parallel with, but seaward from, the Baccaro carbonate front. To date, gas and condensate have been found in these reservoirs. The reservoirs are in the interbedded sand-shale section below the predominately coarse clastic Missisauga Formation. This section is characteristically geopressured but the sands do correlate laterally, and individual sands appear to have sufficient areal extent to provide commercially attractive reservoirs.[1]

North of the Scotian Shelf and east of Cape Breton, the offshore sediments are once again older. Drilling offshore Sydney Basin identified sediments that are an extension of the onshore Sydney Basin and, thus, are from Pennsylvanian through Mississippian in age. The Magdalen Islands Basin, south and west through the Northumberland Strait and including northern Nova Scotia, has the potential to contain a thick Carboniferous sequence with many related evaporitic structures. This was evidenced by the Hudson Bay F-25 well that bottomed in Lower Mississippian at a depth of 3010 m. A second well, Hudson's Bay E-49, had a good show of natural gas and prompted exploration companies to continue their search in this environment. Two subsequent wells drilled in this area were dry.



Another aspect of offshore oil and gas activities: survival training. Shown is an underwater orientation exercise. Photo courtesy Survival Systems Ltd.

2. Exploration

Exploration for hydrocarbons off Nova Scotia began in 1959 when Mobil carried out a magnetometer survey of Sable Island. This was followed by a 1000 km seismic program the next year. The current drilling phase of offshore exploration began in 1967 when Mobil drilled a 4500 m hole on Sable Island. Two years later, Shell Canada acquired a great deal of seismic data on the Scotian Shelf and began an extensive drilling program on the Scotian Shelf.

In 1971, Mobil had their first significant discovery well located on the western tip of Sable Island. By 1978, 70 wells had been drilled, half of them in close proximity to Sable Island. The Venture structure was discovered in 1979 and was delineated by two successful appraisal wells in 1981-82. The Venture structure was declared commercially viable by Mobil in June 1982. To date (July 1983), 81 wells have been completed and seven are currently being drilled (see Appendix I, Figures 4, centerspread, and 5). More drilling and evaluation are necessary to prove the commercial viability of, and possible production from, other existing prospects.

Pipe racks, drill rig on Sable Island.

Under the Canada-Nova Scotia Agreement exploration agreements involving 7.9 million hectares were approved as of June 1983. Work commitments under these agreements involve acquiring 19 750 km of seismic data and drilling 31 wells during the next four to six years in the Nova Scotia offshore. Eight of these wells have been, and are currently being drilled. Exploration agreements are being re-negotiated for an additional 2.22 million hectares. A further 4.74 million hectares of land are under moratorium due to international boundary disputes (see Figure 4, centrespread).

Mobil and partners have signed exploration agreements that commit them to drilling six wells over the next four years. Three of these wells are currently being drilled on the Sable Island Block. One well, Arcadia J-16, was on an untested structure; another, Bluenose 2G-47, offsets a previous shallow hole; Venture B-52 and Venture H-22 are appraisal wells on the Venture field. Shell Canada and partners are currently drilling Glenelg J-48, the second well of its 15-well exploration program (six wells to be drilled on the Slope and nine on the Shelf over the next three to six years). The SDS Vinland is currently drilling Uniacke G-72, the second well to be drilled on the Shell Shelf lands.

Petro-Canada, Husky/Bow Valley have signed an Exploration Agreement for the Esperanto Block that commits them to drilling eight wells over the next three years. The first well, Esperanto B-78, was recently completed.

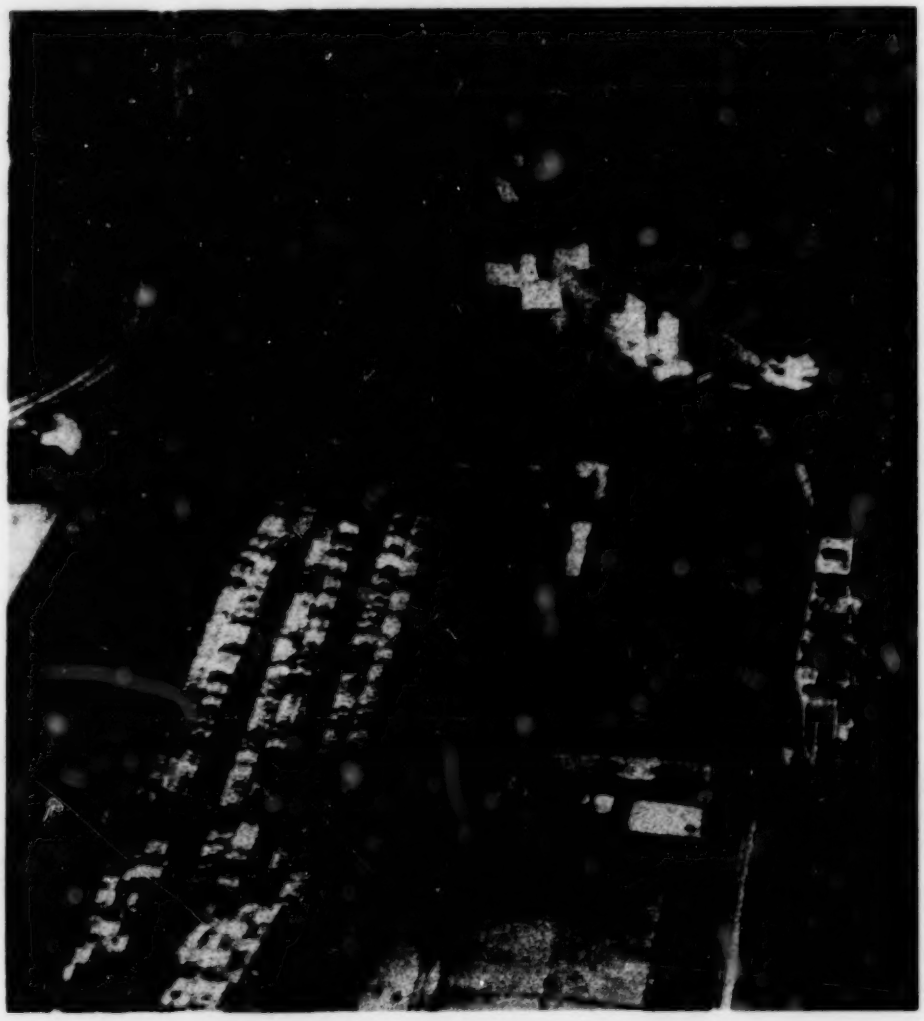
Dome and partners have signed an exploration agreement on the East Sable Block. Home will operate the block and drill two wells over the next two and one-half years. The first well will be spudded by the end of 1983.

Husky/Bow Valley have farmed into Mobil on their South Sable Block and Banquereau Block, an arrangement which commits them to drill up to four wells. They have also farmed into two Onaping Blocks. The Bow Drill II was constructed at the Framnaes Yard (Norway) and is drilling Glooscap C-63 on the central Onaping Block. The Bow Drill III, being constructed at a Saint John (New Brunswick) shipyard, is scheduled to arrive in the offshore scene by late 1983. In the spring of this year, the Husky/Bow Valley group opened an office in Halifax. The group has also established a supply base at Pier 9A in Halifax.

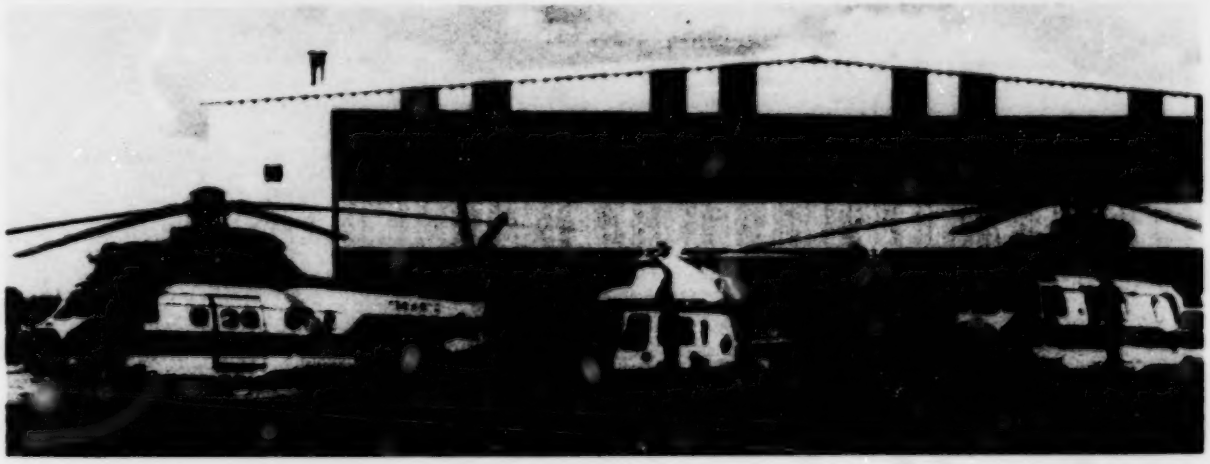
A number of other companies are currently renegotiating exploration agreements that will result in additional drilling.

This year an important phase will be reached regarding certain offshore exploration agreements. Lands will be relinquished from the licensees back to the Crown, a requirement under most exploration agreements. Through this relinquishment process, companies with small or negligible land holdings will have the opportunity to acquire acreage and explore for oil and gas. Approximately 1.29 million hectares of Shell Slope lands were relinquished during the early part of 1983.

At the end of 1982, six rigs were operating in the region offshore Nova Scotia. By the end of 1983, it is anticipated that two more rigs will be active offshore Nova Scotia.



Pier 9, Halifax Harbour. Photo courtesy Shell Canada Resources Ltd.



"Heliport" to open in the Fall of 1983 at the Halifax International Airport to service the offshore oil and gas industry. Photo courtesy Seeland Helicopters Ltd.

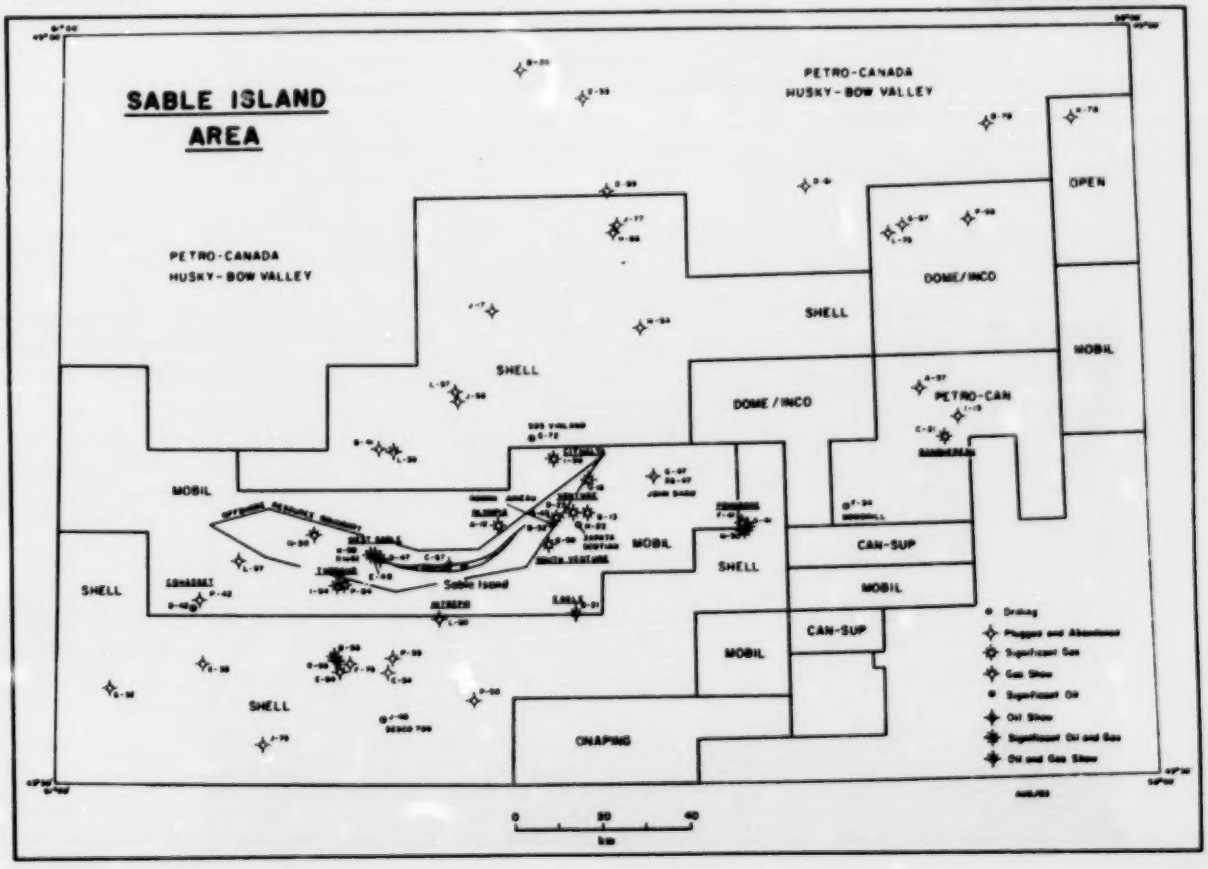
3. Significant Discoveries

To date, 12 discoveries in the offshore region have been deemed significant. A discovery is significant if the first well on a geological feature shows the existence of hydrocarbons which, when flow tested, appear to have potential for production. These discoveries, shown in Figure 5, are as follows:

1. The **Venture Structure** is located 12 km east of Sable Island. Four wells have been drilled and one is being drilled on this structure — the discovery well and four appraisal wells. The Venture D-23 discovery well was completed in May, 1979, to a total depth of 4937 m. The combined flow rate for the zones tested was 1 257 408 m^3/d of gas and 87 m^3/d of condensate.

The second well, Venture B-13, located 3 km southeast of D-23, was completed in June 1981 to a total depth of 5354 m. The combined flow rate for the zones tested was 2 299 584 m^3/d of gas and 184 m^3/d of condensate.

Figure 5. Large-scale map of Sable Island area



Venture B-43, the third well, was completed in April 1982 to a total depth of 5872 m. The combined flow rate for the zones tested was 2 690 400 m^3/d of gas and 334 m^3/d of condensate. Test results from this well confirmed that significant hydrocarbons exist in this structure.

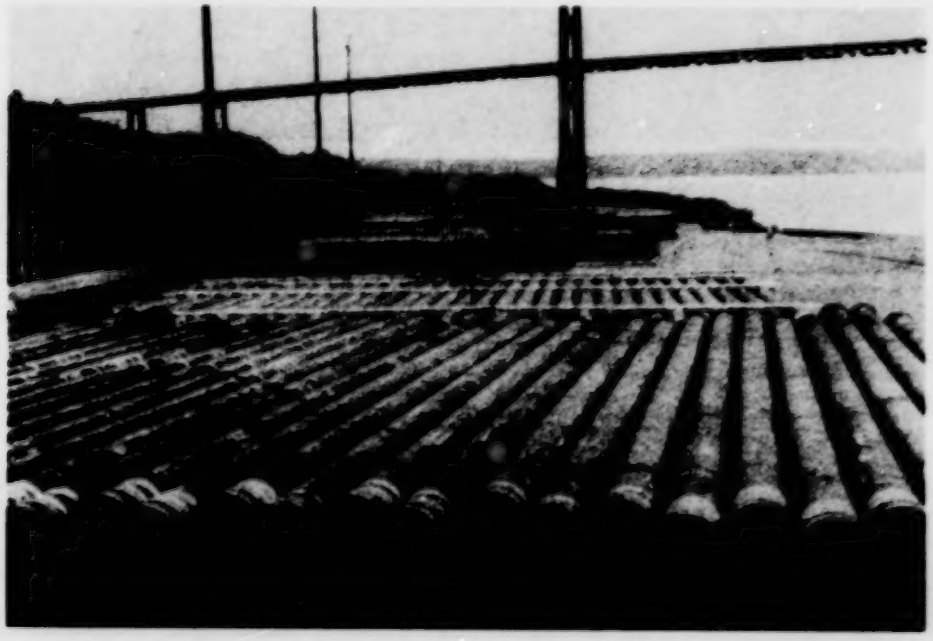
The fourth well, Venture B-52, was drilled to 5960 m and is being followed by an extensive testing program. This well will help to define the southwest lobe of the Venture structure and, the fifth, Venture H-22 will appraise the southeastern portion.

The reserves estimated to date for the Venture structure are 72 billion m^3 of natural gas with associated condensates. Mobil, operator of the Venture Project, is proceeding on development studies with production scheduled for late 1987 or early 1988.

2. The **South Venture Structure** is located 5 km southwest of the Venture field. One well (0-59) was completed in January 1983 to a total depth of 6176 m. The combined flow rate for the zones tested was 2 645 088 m^3/d of gas and 541 m^3/d of condensate. Additional exploration is necessary to determine the extent and production potential of this structure.

3. The **Olympia Structure** is located 13 km west of the Venture field. One well (A-12) was completed in January 1983 to a total depth of 6064 m. The combined flow rate for the tested zones was 1 585 920 m^3/d of gas and 134 m^3/d of condensate. Additional drilling is necessary to determine the size and potential of this structure.

4. **Citnalta** is located 16 km northeast of the eastern tip of Sable Island. One well (I-59) was completed in April 1974 to a total depth of 4575 m. The combined flow rate for the tested zones was 555 072 m^3/d of gas and 212 m^3/d of condensate. Additional drilling is necessary to confirm the presence of a significant hydrocarbon reservoir.



Drill pipe storage at Pier 9, Halifax Harbour. Photo courtesy Shell Canada Resources Ltd.

5. **Intrepid** is located 12 km south of Sable Island. One well, L-80, was completed in August 1974 to a total depth of 4162 m. The combined flow rate for the tested zones was 512 592 m^3/d of gas and 30 m^3/d of condensate. Additional drilling is required to demonstrate the existence of a significant hydrocarbon reservoir.

6. **Cohasset** is located 48 km west of the western tip of Sable Island. Two wells have been completed on this feature. The first well (D-42) was completed to a depth of 4427 m in July 1973. The combined flow rate for all zones tested was 2719 m^3/d of gas and 249 m^3/d of oil. The P-42 stepout well, 1 km northwest of D-42, was completed in July 1978 to a depth of 2591 m. This well tested no hydrocarbons, thus discouraged any further exploration at the time. More drilling is needed to evaluate the potential of this area.

7. **Thebaud Structure** is located 7 km southwest of the western tip of Sable Island. Two wells were completed on this structure. The first discovery well (P-84) was drilled to 4115 m, finishing in October 1972. The combined flow rate for the zones tested was 849 600 m^3/d of gas and 16 m^3/d of condensate. The second well, (I-94) 1 km southwest of P-84, was completed in May 1978 to 3962 m. The combined flow rate for the zones tested was 387 984 m^3/d of gas and 64 m^3/d of condensate. The I-94 well did not encounter the same pay section uphole as did P-84 but several significant gas zones encountered below 3600 m correlated with the discovery well. The possible continuity of reservoir quality rock will require additional drilling.

8. **Eagle** is located 20 km southeast of the eastern tip of Sable Island. The only well (D-21) was drilled to 4660 m in June 1972. Of the three production tests done, one test flowed 39 648 m^3/d of gas but declined rapidly to 4 248 m^3/d. Mechanical logs indicate 61.6 m of formation to be gas bearing. Follow-up drilling is necessary on this feature.

9. **Primrose** is located 80 km east of the eastern tip of Sable Island. A total of three wells were drilled on this structure. The N-50 well was completed in April 1972 to a depth of 1714 m. The combined flow rate for the zones tested was 1 430 160 m^3/d of gas and 103 m^3/d of oil. The other two wells (A-41 and F-41) had small gas shows. Further exploration is required in this area.

10. The **West Sable E-48** well is located on the westernmost tip of Sable Island. The E-48 well was drilled to 3603 m in October 1971. The combined flow rate for the zones tested was 1 812 480 m^3/d of gas and 649 m^3/d of oil from Cretaceous age sediments. A total of seven delineation wells have been drilled on this structure.

11. The **West Sable 0-47** well was completed in June 1972 to a depth of 4199 m. The combined flow rate for the zones tested was 172 752 m^3/d of gas and a trace of oil from the Jurassic formation. Because these intervals in the West Sable area are severely faulted, the reservoirs are discontinuous and have a low estimate of oil and gas reserves.

12. **Petro-Canada Banquereau C-21** is 96 km east northeast of Sable Island. The C-21 well was completed in July 1982 to a depth of 4991 m. The flow rate for the zone tested was 642 864 m^3/d of gas and 16 m^3/d of condensate. A subsequent well, Petro-Canada North Banquereau I-13, encountered no significant hydrocarbons.

4. Development — Venture Project

Mobil Oil and its partners (Petro-Canada, Texaco, Nova Scotia Resources Limited, East Coast Energy Limited) are proceeding with plans to produce natural gas and condensate from the Venture field, located 210 km offshore Nova Scotia and 16 km east of Sable Island in 22 m of water. Mobil estimates recoverable natural gas reserves to be 72 billion m^3. Proposed gas production is 11.32 million m^3/d with a gas sales rate of 10.2 million m^3/d. The field is expected to be in production by early 1988.

Facilities described in this section are based on preliminary designs and are subject to change as new information about the Venture Structure is acquired from the drilling of the Venture B-52 well and subsequent appraisal wells. The production facility currently envisioned consists of two offshore complexes (Figure 6), each including two separate

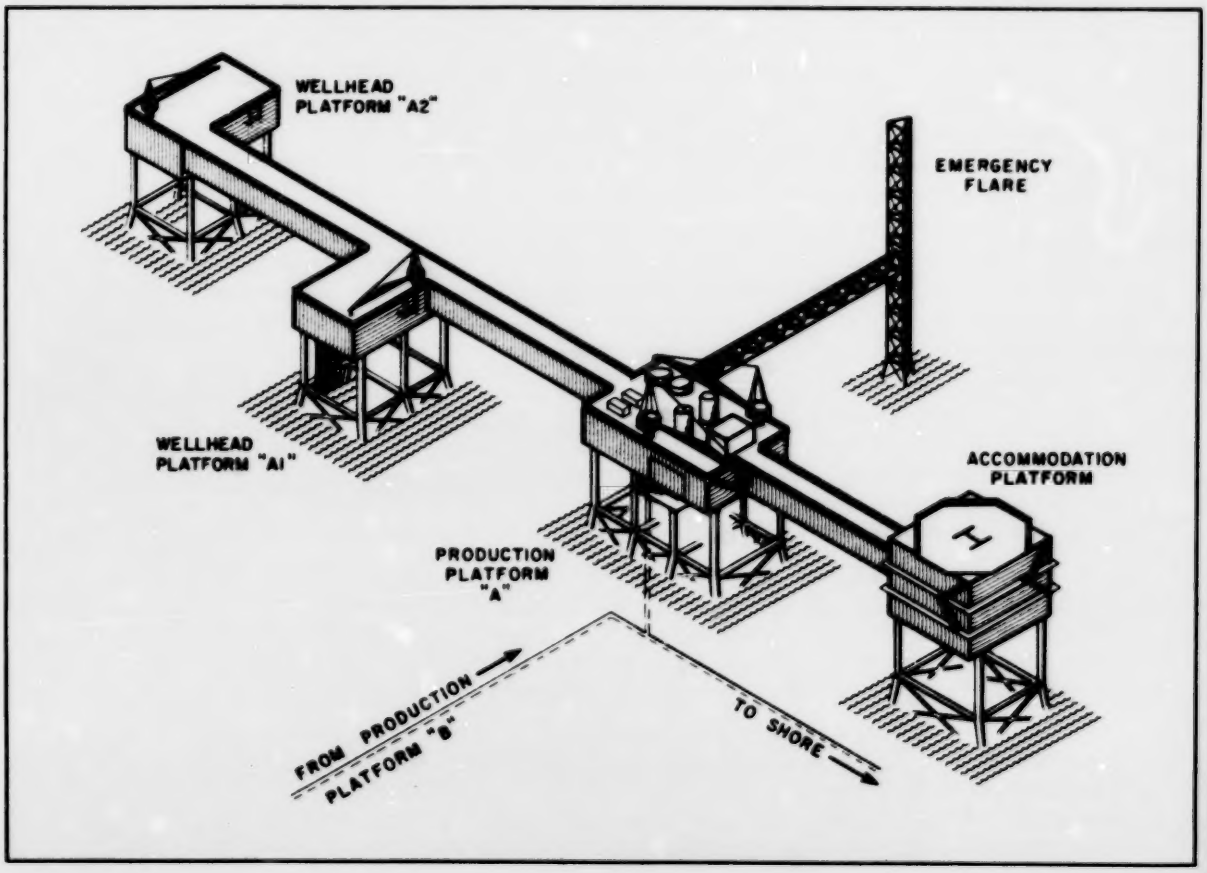


Figure 6. Offshore production complex Schematic courtesy of Mobil Oil

wellhead platforms, a processing and utilities platform, a separate flare structure, and an accommodation platform. There will be 16 producing wells. One complex will be positioned in the east lobe of the field and the other in the west lobe.

From the production facilities, the preferred system for moving the gas and condensate to land is by a 914-mm subsea pipeline approximately 210 km long in a maximum water depth of 125 m. At landfall in the Country Harbour area of Nova Scotia, west of the Strait of Canso, the subsea pipeline will merge into a slug catcher. At this facility, the gas and condensate will be separated and directed into separate pipelines to the gas plant. The gas pipeline will be 610 mm and the condensate line will be 324 mm.

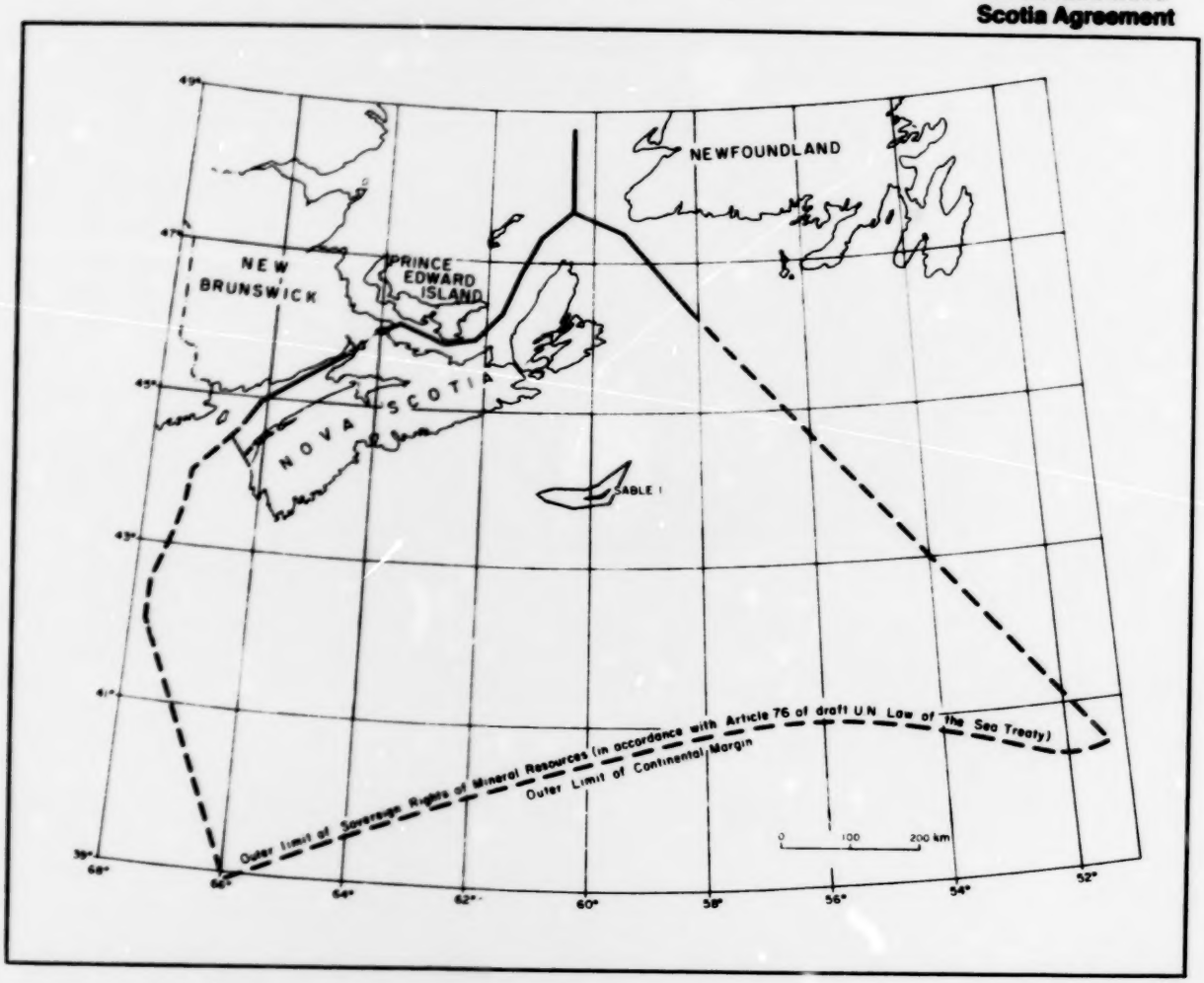
At the gas plant, the water and remaining condensate will be removed from the gas, the gas (mostly methane and ethane) will be brought to the contracted sales specifications, and the natural gas liquids will be fractionated to recover hydrocarbons such as propane, butane and pentanes plus. From the gas plant, the gas will enter a regional pipeline for transmission to markets in the Maritimes and the northeastern United States.

5. Canada-Nova Scotia Agreement

In March 1982, the Governments of Canada and Nova Scotia signed the Canada-Nova Scotia Agreement on Offshore Oil and Gas Resource Management and Revenue Sharing. This agreement provides a framework for the orderly exploration, development and production of Nova Scotia's offshore petroleum resources.

The administration of resource development is done jointly by the province and the federal government. The offshore region to which the Canada-Nova Scotia Agreement applies is shown in Figure 7.

Figure 7. Offshore Region covered by the Canada-Nova Scotia Agreement



A Canada-Nova Scotia Offshore Oil and Gas Board was established under the agreement. This board is comprised of five members — three appointed by the federal government and two appointed by the Nova Scotia government. The Nova Scotia members have the right to delay the execution of certain key decisions for specified periods. The board advises and acts under the authority of the federal minister of Energy, Mines and Resources on all matters pertaining to the offshore area.

The Canada Oil and Gas Lands Administration (COGLA) is the federal agency designated to administer offshore oil and gas resource activities in the Canada Lands. A COGLA office has been established in Halifax to carry out the above mentioned function for the offshore region. The board directs the activities of COGLA with respect to the offshore region.

The Department of Mines and Energy acts on behalf of the provincial government in energy and mineral issues. The Petroleum Resources Section, within the Energy Resources Division of the Department, oversees exploration and development of Nova Scotia's petroleum resources. This section advises the Nova Scotia members of the Canada-Nova Scotia Offshore Oil and Gas Board on key issues such as exploration agreements, provisional leases and production licenses. It also cooperates with COGLA and the oil industry, advising on operational activities such as testing and safety programs.

A number of committees were established under the agreement. The Canada-Nova Scotia Executive Committee on Economic and Social Benefits was set up to assess and report on the economic and social benefits related to offshore oil and gas resource activities. In addition, environmental committees and fisheries committees were formed to assess and report on the impacts of the offshore activites in these areas.

Figure 7 shows the boundary area around Sable Island in which, under the agreement, 100 per cent of the revenues flow to Nova Scotia for the duration of the agreement. In the rest of the area covered by the agreement, revenues from the offshore resources will flow to Nova Scotia until the province reaches a level of 110 per cent of the Canadian average fiscal capacity per capita plus an adjustment for the level of unemployment. At this point, the revenues will be shared between the federal and provincial governments.

B. Onshore

1. Geological Setting

The existence of widely scattered traces of oil in the form of seeps (at Lake Ainslie) and asphaltic material in the marine Windsor Group with pyrobitumen in the non-marine Horton, Pictou and Stellarton Groups, has been known since the 1800s in Nova Scotia and has prompted various exploration programs.

These formations, of early Carboniferous age, are found in the sedimentary basins, including the Minas Basin, Cumberland Basin, Stellarton Gap-Pictou Basin, Antigonish Basin, and Inverness-Mabou sub-basin (see Figure 8). The rocks consist of sandstone, siltstone, limestone, shale, some conglomerate and coal, as well as evaporites such as gypsum, anhydrite and halite (common salt).

The Horton Group, which underlies the Windsor, is made up of continental fluvio-lacustrine (river and lake) deposits favourable to the formation of coal, though in most cases it has not been suitable for hydrocarbon generation. An exception is the Stellarton Gap-Pictou area where there were repeated successions of thick sediment deposition. Small quantities of petroleum in intercalated sandstones have been found but there is a lack of stratigraphic and structural traps.[2] Oil shales were discovered in Pictou County at Stellarton in 1859. These were mined as oil-coal (stellarite and torbanite), were retorted and distilled to yield oil, and were used as a mixture with bituminous coals for gas-making. The oil shales were tested by several sources in Scotland and found to yield from 3.0-126 gal/ton.[3] The mines were short-lived, owing to the discovery of oil in the United States.

Beds of petroliferous sandstones are known in the Lake Ainslie area, overlying thin limestone and black shale layers thought to be the source of the seeps.[4,5] An alternate source is within the Windsor Group, as the strata are faulted against the Horton in some places.

Within the Horton Group in New Brunswick, located in the Albert Formation at Stony Brook, is a small oil and gas field. It is a commercial field and it has produced 753 312 000 m^3 of gas and 118 000 m^3 of oil since its discovery in 1909. Gas production was 2 993 424 m^3 and oil production 1 526 m^3 in 1971.[6]

Evaporites formed the earliest unit in the Windsor Group, followed by deposition of clastic sediments and carbonates, both good reservoir rocks. Evaporites in the form of halite, gypsum and barite have continuously been mined at a commercial level from the Windsor Group in Nova Scotia (see Figure 8).

The search for petroleum is restricted to the Carboniferous as rocks pre-dating this age were subjected to different degrees of metamorphism and, as a result, have virtually no petroleum potential. Carboniferous sediments were deposited in narrow elongated basins and were bordered by uplands in Central New Brunswick to the northwest and by an

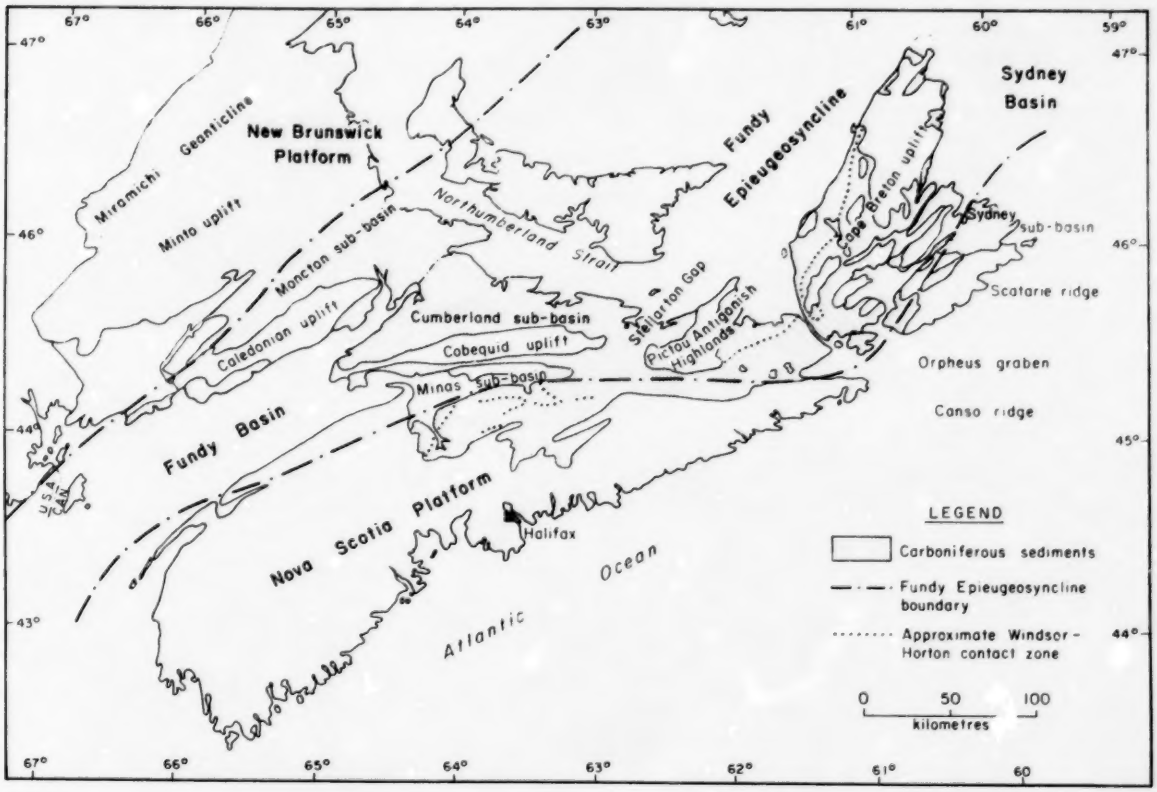


Figure 8. General structure and Carboniferous age sediments of Nova Scotia

uplifted region of pre-Carbonifeous rock belonging to the Acadian Orogeny to the south. The first sediments deposited in the subsiding Fundy Basin were derived from both bordering areas and so are continental in origin. The Horton Group in Middle Devonian to Mississippian (see geologic time scale Figure 9), rests unconformably upon eroded Acadian Orogen (generally Cambrian and older), and consists of red to grey sandstone, conglomerate, siltstone, and shales. As the source areas of the sediments were eroded, the coarse clastics were replaced by finer fractions of grey sandstone and shale. This indicates a change from piedmont to a fluvio-lacustrine environment. In addition, the presence of coal in parts of Cape Breton and Nova Scotia indicates the former existence of swamps or marshes. In late Horton, there was a renewed uplift with deposition of salt in some locations. Arid conditions signalled the end of the Horton and transition to Windsor Group.

A transgression of the Atlantic Ocean in the form of an elongated arm invaded the low-lying areas of the Fundy Epieugeosyncline (Basin). Since the climate was semi-arid and the terrain mainly flat alluvial plains, thin beds of fine-grained limestone were deposited upon Horton Group red beds and overlapped locally on basement. A restricted shallow marine environment ensued with deposition of thick sequences of salt, gypsum, anhydrite and carbonate. Tectonism, accompanied by volcanic activity during or after deposition of evaporites, produced salt flowage in the epieugeosyncline and other low-lying areas. This accounts for the thick accumulations in salt domes, diapirs and ridges. In between, carbonates,

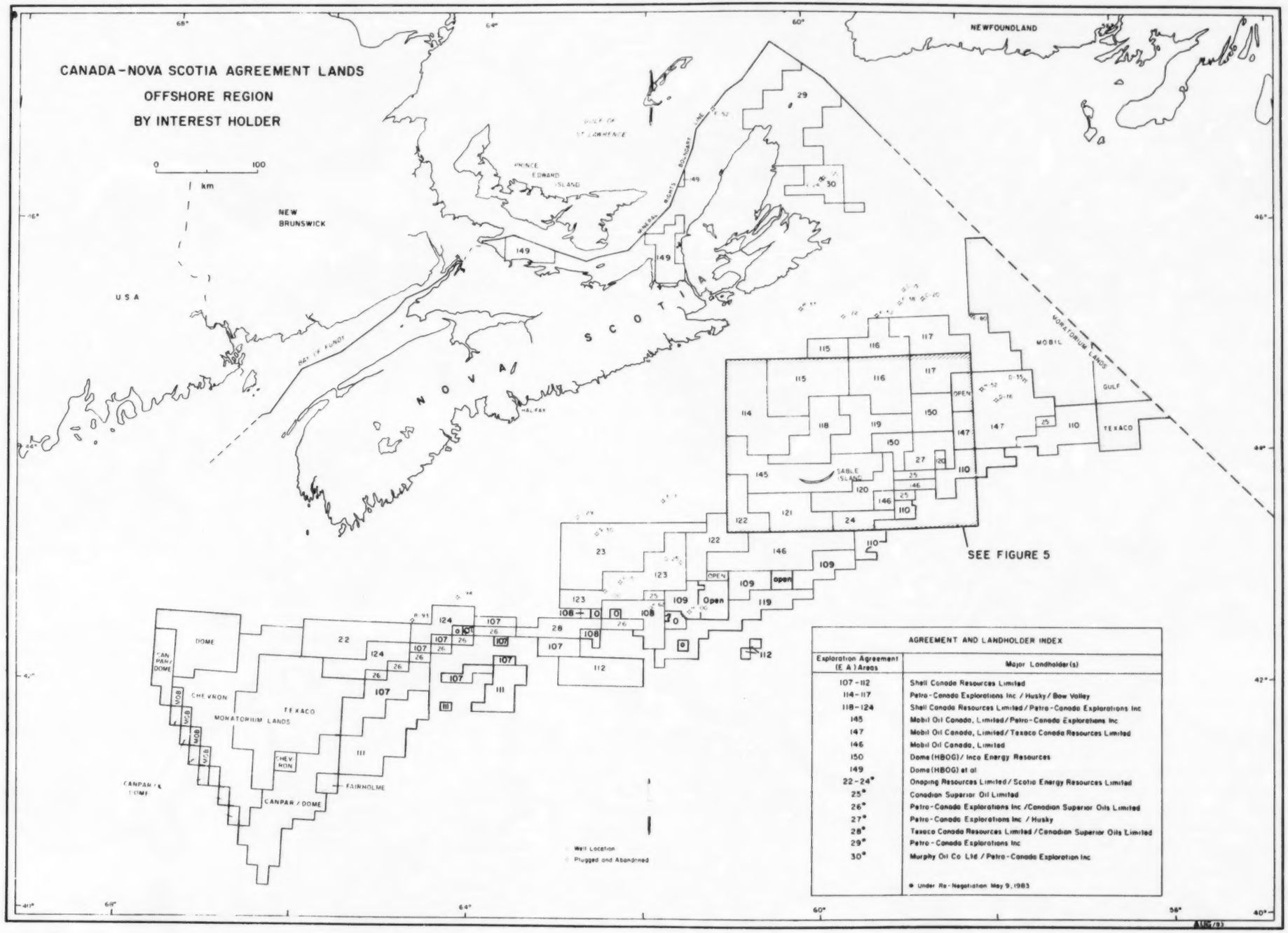


Figure 4.
Canada-Nova Scotia Agreement Lands Offshore Region by interest holder

clastics and minor evaporites were deposited in marine, shallow marine and continental environments. The sea level rose and fell due to cyclical uplift and subsidence and was followed by a regional uplift and a gradual withdrawal of the Windsor Sea.

The Windsor Group consists generally of thick members of massive to poorly bedded red and greenish-grey mottled siltstone, shale and sandstone interbedded with gypsum, anhydrite, shale and thin tabular sequences of limestone and dolomite. In areas adjacent to Windsor Uplands, conglomerate and sandstone are common; in low-lying terrain and areas far from shore, evaporites and carbonates predominate.

Regional and local uplift, begun during Windsor sedimentation, expelled the Windsor Sea and subsequently changed the depositional environment from marine to brackish fluvial and fluvio-lacustine. The Canso Group is mainly an offlap sequence in which thinly laminated red and grey shale, sandstone and minor limestone, and widespread distribution of ripple marks, mud cracks, fresh water shells and plant remains, indicate a fluvial to fluvio-lacustine environment in a semi-arid climate.

Regional uplift continued during deposition of Riversdale Group rocks. Maximum tectonism was concentrated in the southwestern part of the epieugeosyncline, indicated by highly contorted Upper Paleozoic rocks overlain by thick deposits of coarse clastics (red and grey sandstone and shale). Here the Caledonian and Cobequid uplifts dissected the larger basins into the Moncton sub-basin, Cumberland sub-basin, Minas sub-basin and Fundy Basin. Where folding was less intense (e.g., Antigonish and western and southern Cape Breton Island), non-marine red and grey sandstone, siltstone, shale and coal were deposited. Cross beds, abundant plant remains, coal, fresh water ostracods, mud cracks and ripple marks indicate a fluvio-lacustine to paludal (or swamp) environment.

The Cumberland Group rests comformably on the Riversdale Group in the type area and unconformably or disconformably in other areas. The group is made up of non-marine red and grey conglomerate, sandstone, shale and mineable coal seams. At the Stellarton Gap, the Group consists mainly of red sandstone with a basal conglomerate. The type section of the Pictou Group is a sequence of non-marine, dark red sandstone, grey sandstone, arkosic grit, dark red shale, mudstone and minor grey shale.

As regional uplift continued during deposition of Cumberland and Pictou Groups, coarse conglomerates of the Cumberland Group were deposited along the north and east side of the Cobequid uplift (the Cobequid and Antigonish uplifts provided the sediments). The Cumberland, although very thick, spans a brief interval in geologic time. The rapid subsidence and deposition in the western Cumberland sub-basin is indicated by the preservation of trees in an upright position. The deposition was a result of a balance between rapid uplift of the provenance area and rapid subsidence of the basin, as well as migration of Windsor evaporites.

When the upper part of the Cumberland Group was being deposited, non-marine fluvial and fluvio-lacustine red and grey sandstones, shales and minor conglomerates of the Pictou Group were deposited in other areas. These Pictou sediments unconformably overlaid older Paleozoic rocks and onlapped the basement. Western Cape Breton Island, Sydney Basin, Stellarton Gap and Minto Uplift were swamp areas where thick coal deposits

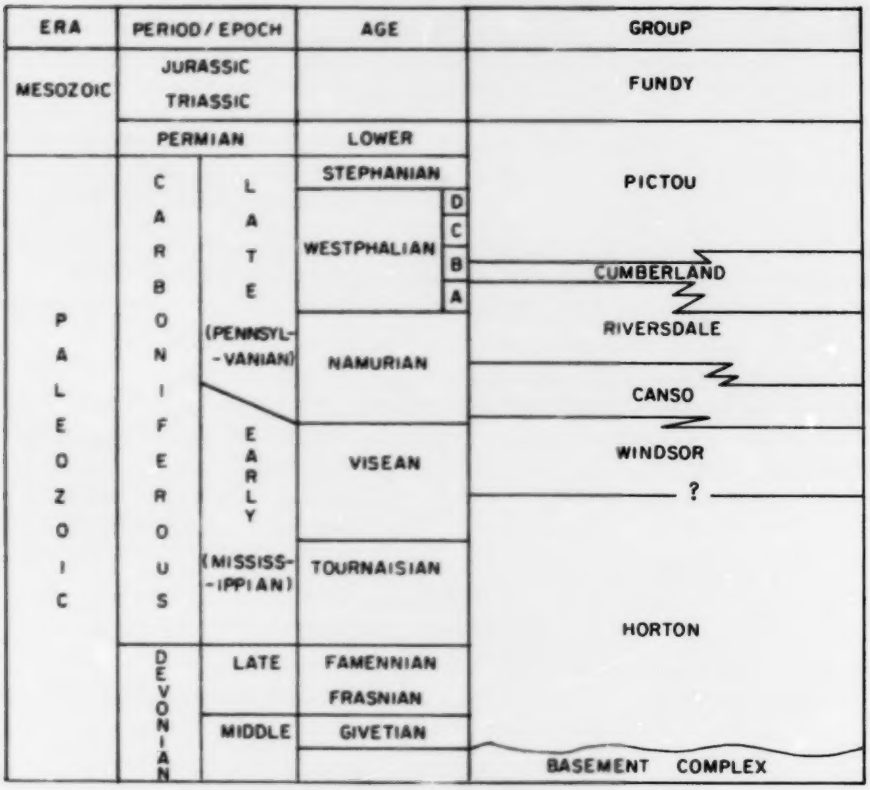


Figure 9. Geological time scale — onshore

accumulated. The climate during the deposition of the non-marine Cumberland and Pictou Groups was temperate and pluvial.[7]

In the late Carboniferous, swamps flourished although not long enough to generate thick deposits favourable for the generation of petroleum. Pyrobituminous material, in part of algal origin, formed in the Stellarton area. Small amounts of gas and minor oil staining reported in the Pictou Group are in interbedded sandstones and may have originated from the decomposition of plant material. The source is most likely to have been in the non-marine fine-grained argillaceous siltstones.

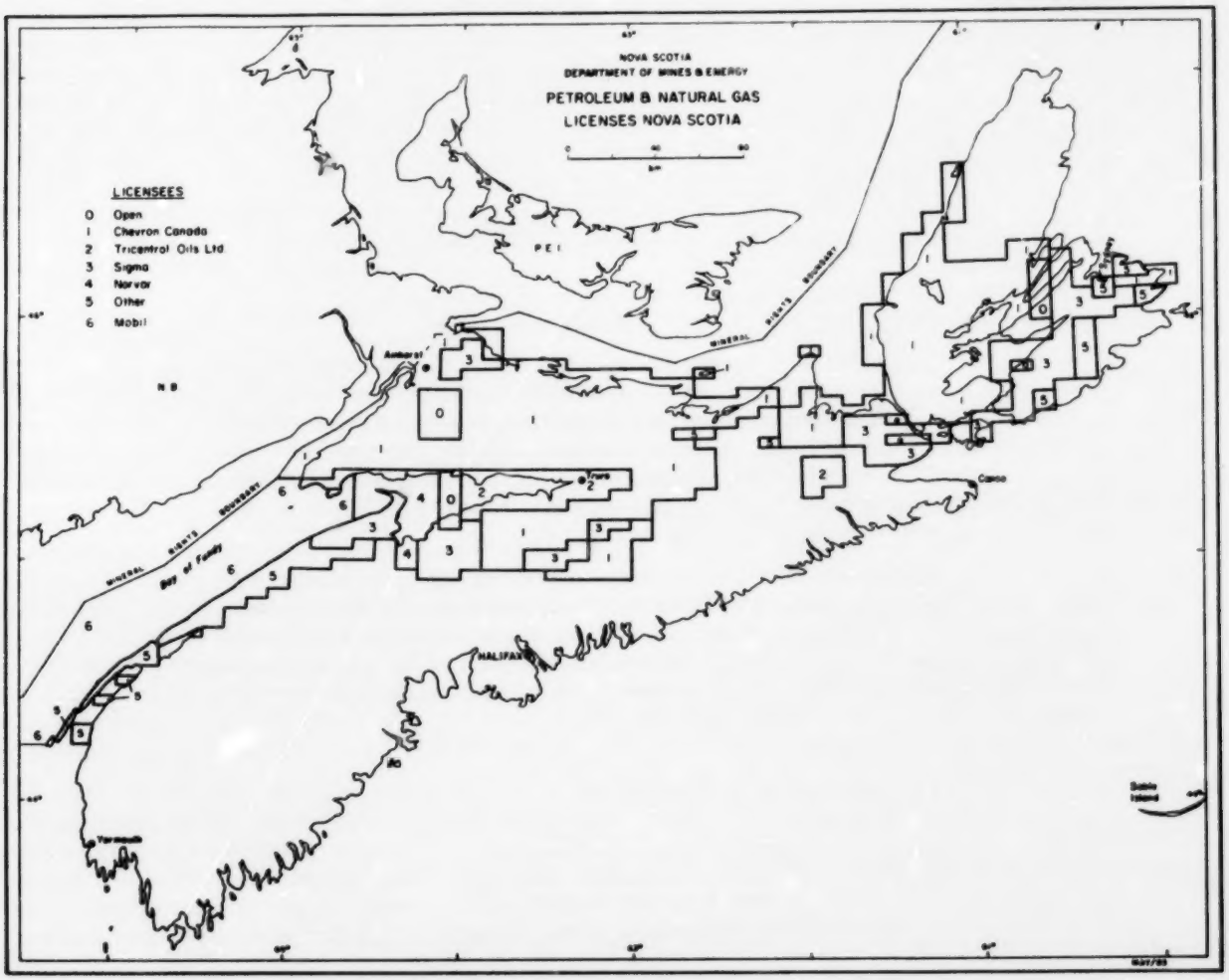
The main potential for hydrocarbons in these rocks depends on good local porosity, the migration of hydrocarbons from the underlying Horton and Windsor Group rocks, and hydrocarbons in association with coal bearing horizons. Movement of Windsor Group salt has probably produced a variety of traps in post-Windsor sediments flanking and overlying high relief diapirs.[6]

2. Exploration

Exploration for hydrocarbons in the province began in the mid 1800s when surface seeps, oil-filled cavities in gypsum, and petroliferous sandstones were discovered in several counties. Numerous accounts have been recorded in the literature.[2]

Various drilling programs have encountered subsurface natural gas, sandstones and limestones with strong petroliferous odours and gypsum with oil in vugs and cavities. None of the discoveries have been commercial, although there is a report of approximately 100 gallons of oil from a hole near MacIssac Point at Lake Ainslie in 1864.[8]

Figure 10. Petroleum and natural gas licenses Nova Scotia



Over the past 25 years, approximately 20 wells with petroleum significance have been drilled onshore (see Appendix II). The onshore wells have been drilled in the basinal areas around the province and are concentrated in the Cumberland and Stellarton Gap-Pictou Basins, Lake Ainslie and Bras D'Or Lakes areas. A Chevron-Irving joint venture drilled several holes in the Bras D'Or Lakes-Malagawatch area in late 1979. The holes are listed as dry and abandoned. In the Bras D'Or No. 1 well, however, during a bottom hole drill stem test, 22 m of mud cut oil was brought to surface.

Chevron, in partnership with Irving, drilled the most recent hole in Pictou County, Scotsburn No. 2. It was completed in November 1981 to a total depth of 2593 m and was classed as a dry and abandoned well.

Chevron undertook a seismic program in the Lake Ainslie region of Cape Breton early in 1983 and is currently reviewing its data from the Minas Basin, Cumberland Basin and Cape Breton Blocks (see Onshore License Map, Figure 10).

During 1982, a number of companies including Tricentrol, Sigma, MEX and Norvar were involved in geological reconnaissance mapping, aerial photo interpretation, research and sample analysis.

Tricentrol carried out an experimental seismic program in June 1983 on its Cobequid Bay Block and is presently evaluating geological information acquired during the previous year.

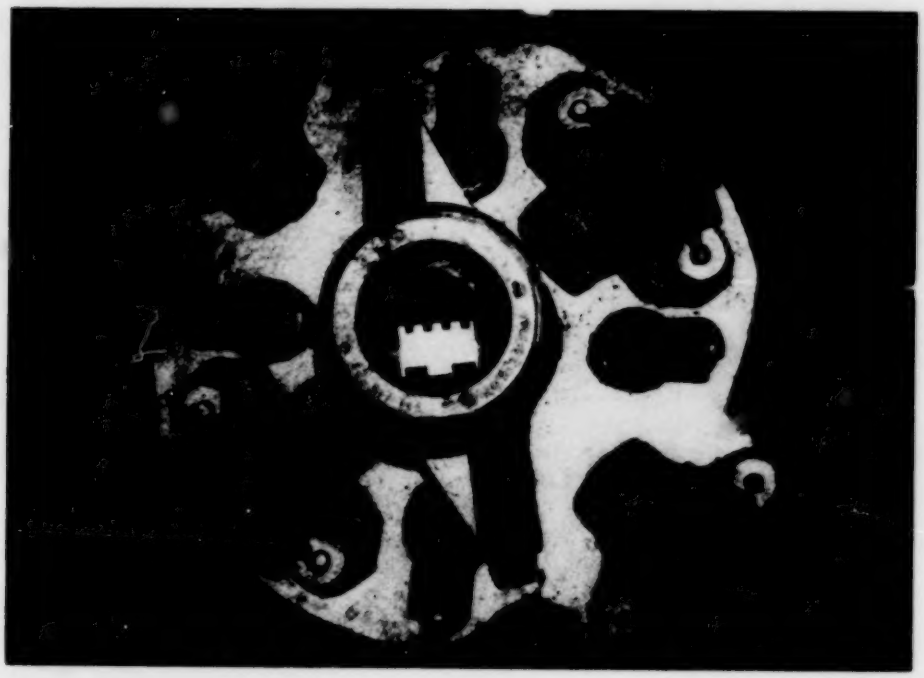
MEX and Norvar will be continuing evaluations of their lands, and Sigma, in conjunction with other license holders, has effected an agreement under which it will drill a minimum of six wells this year.

The Canada-Nova Scotia agreement recognizes that the Bay of Fundy comes under provincial jurisdiction. Chevron farmed into Mobil lands and conducted approximately 400 km of seismic in the Bay in the summer of 1982. Additional seismic may be conducted in 1983-84.

3. Role of the Department of Mines and Energy

The Department of Mines and Energy acts on behalf of the Government of Nova Scotia as owner, planner and regulator in energy and mineral issues. As owner, the department analyzes exploration and development proposals, assigns leases for exploration and development projects, and sets the terms of those rights including items such as royalties and expiry dates. As planner, the department, in co-operation with other government departments and groups in the private sector, prepares for the impact of major energy developments. As regulator, the department monitors the construction and operation of energy projects to ensure that they meet accepted standards of safety and performance.

The Petroleum Resources Section of the Energy Resources Division is the section of the department specifically involved in petroleum resource issues, such as the administration of petroleum rights and the inspection of operations. This section also acts as the liaison with other provincial government departments (e.g., Department of Environment) when co-ordination is required to allow petroleum activities to proceed.



Drill bit, to drill large diameter holes (hole opener), used in combination with a "pilot" bit.

PART II

OIL AND GAS INFORMATION

Diving bell, being lowered into the ocean, is preparing to do a rig inspection. Photo courtesy K.D. Marine.

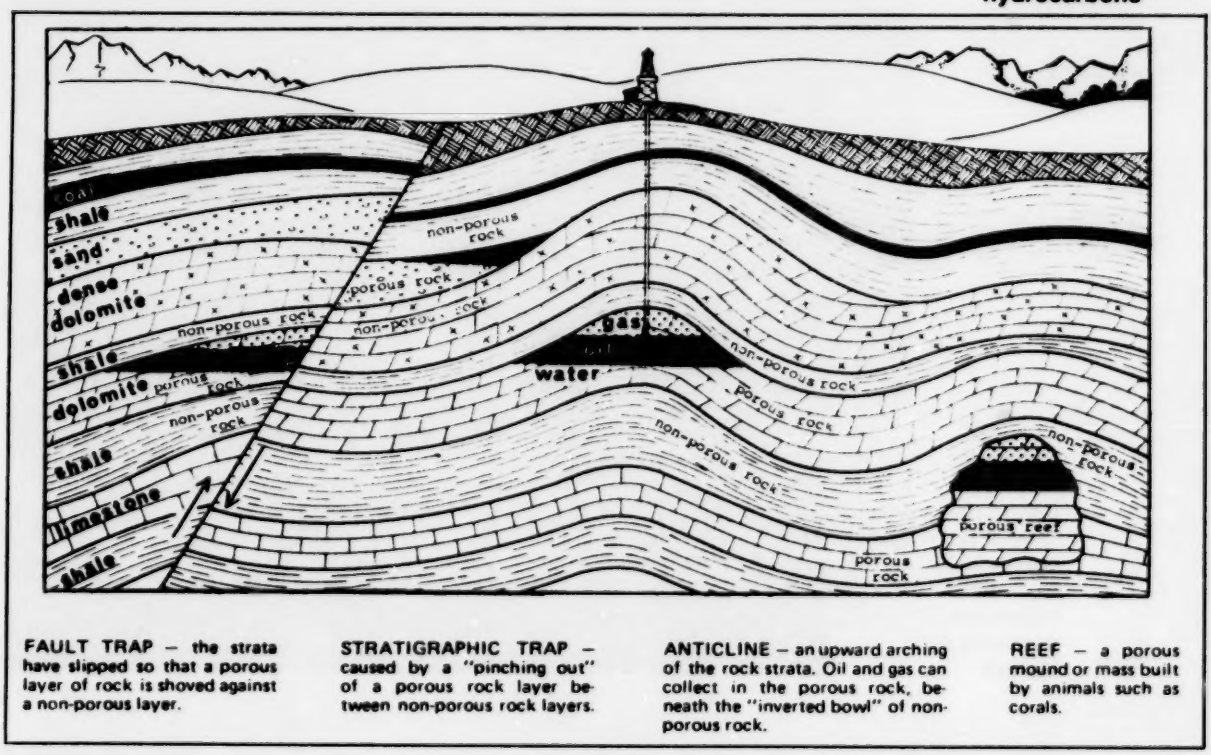
1. Origin and Accumulation

Petroleum (from Greek meaning "rock oil") is a general term used to include all generated and commercially produced hydrocarbons from natural gas (methane) to crude oils and solid (asphaltic or paraffin) residues. This encompasses a tremendous range of molecular structures with a large spectrum of physical properties combined with numerous impurities.

Petroleum is always found in, or associated with, sedimentary source rocks which, as newly deposited sediments, contain an abundance of plant or animal remains (organic material). The actual processes that took place to change organic remains into complex and varied hydrocarbons are only partly known because the time element — thousands of years — is not reproducible in laboratories. Evidence indicates that plant life is probably predominant over animal life as a basic contributor.

Life forms have proliferated since Cambrian time (600 million years ago); commercial petroleum is therefore found in sedimentary rocks of all ages, in generally increasing quantities, up to recent times. Petroleum accumulated in various areas of the world during different ages because of environmental conditions. In many areas, accumulations from different ages

Figure 11. Geological traps for hydrocarbons



FAULT TRAP – the strata have slipped so that a porous layer of rock is shoved against a non-porous layer.

STRATIGRAPHIC TRAP – caused by a "pinching out" of a porous rock layer between non-porous rock layers.

ANTICLINE – an upward arching of the rock strata. Oil and gas can collect in the porous rock, beneath the "inverted bowl" of non-porous rock.

REEF – a porous mound or mass built by animals such as corals.

are superimposed in rocks that vary in age by more than 200 million years. Even "new" rocks of the Quaternary Period (the last one million years) contain petroleum oils and gases although in only a few cases have these had time to migrate into suitable reservoirs from which they can be commercially recovered.

To be recoverable, hydrocarbons must leave their disseminate and miniscule state in the fine grained source rocks and move into porous sandstones, limestones or fractured rocks (reservoirs), where they concentrate and can be withdrawn through drilled holes. Contrary to popular belief, oil does not exist underground in pools or lakes but is found in the pore spaces of rock. The mechanism of movement or migration of the hydrocarbons to the pore spaces is largely unknown. What is known is that this movement is aided by the presence of water (usually salt water) in the sediments and by compaction (squeezing), a result of burial under additional sediments.

This is illustrated by the accumulation of billions of cubic metres of oil and gas in the relatively small volumes of reservoir rock that contain our present giant fields.

The movement of hydrocarbons into a porous reservoir is, however, only the first step. The migration continues in the porous formation until it escapes to the surface (as at the Athabasca tar sands in Alberta) or is retained below by some subsurface barrier called a trap. The shapes and styles of traps are many but are usually related to the geological history of any particular area (Figure 11). The common element in all traps is that further migration or flushing (by water) of the hydrocarbons toward the surface is prevented by overlying impermeable formations — as an inverted dish will retain air when immersed in water.

A further requirement of the trap is that it be preserved. Trapped oil and gas can be lost by faulting, as at the Santa Barbara Channel, where seepage to the seafloor is slow but continuous. It is very possible that more oil and gas have been "lost" during geological time than have been preserved in traps discovered thus far.

In their natural states, oil and gas exist at a pressure greater than atmospheric, a condition which, when tapped, forces the liquid and gases to flow upwards. This is called a "primary recovery". The rate oil will move through the rock towards the well bore depends on the reservoir pressure, the pressure at the bottom of the well, the permeability of the rock, and the viscosity of the oil. As the oil is removed from the rock, the pressure of the reservoir decreases, and consequently, the rate of production tends to decline unless the pressure is sustained. The producer must then turn to artificial methods to restore reservoir pressure. This is called "secondary" or enhanced recovery and is accomplished by injecting water, natural gas or chemicals into the reservoir to force the petroleum through the rock and up the well bore.

2. Exploration Procedures

Oil and gas are relatively inert and have no particular qualities that allow specific measurement from a distance. The geologist and geophysicist use both "direct" and "indirect" methods to discern the geological structures in the subsurface which could comprise a trap for accumulation. Geological methods include a study of the surface rocks, or (where exposed) sea floor beds and a study of subsurface rocks using samples and downhole logs from previously drilled holes. Downhole logs have several uses and are one of the most important tools of exploration geology. By lowering electrodes into the hole on an insulated cable, the electrical resistance and other mechanical properties of the penetrated formations can be measured and recorded at the surface (Figure 12). Porosity and lithology can be interpreted from the logs. For example, sandstone saturated with salt water has a low resistance while sandstone filled with oil and gas has a high resistance. Oil and gas may be indicated by using a combination of logs and a precise depth of their location can be determined. The logs are also of great value in correlating and evaluating formations between wells to help produce an interpretation of the potential of the area under study.

Geophysical methods include measurements of magnetic or gravity forces, radiometric or electrical characteristics, or acoustic (sound) wave propagation, called seismic. Seismic is the predominant geophysical method and has been used for more than 50 years. For offshore exploration, it is the primary forerunner to pinpoint drilling locations.

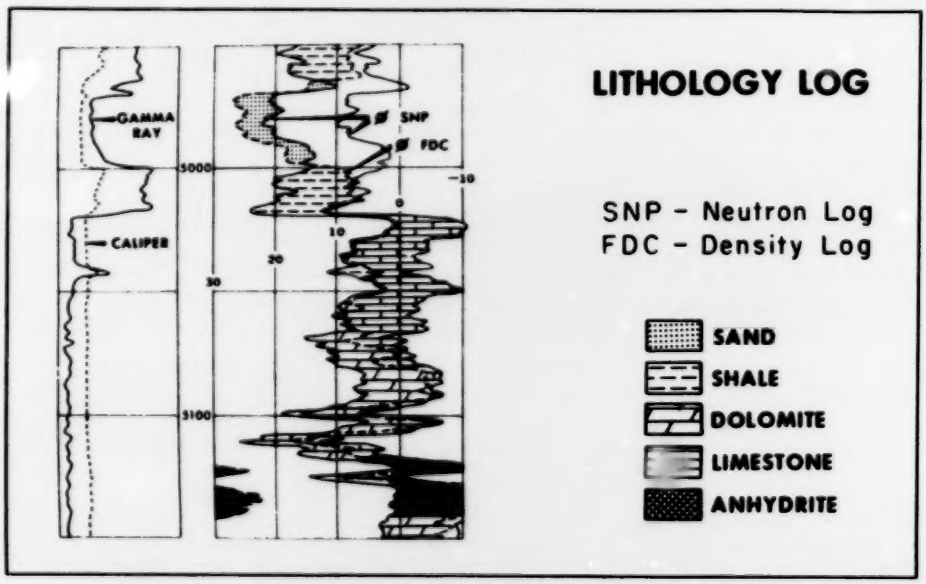


Figure 12. Lithology Log

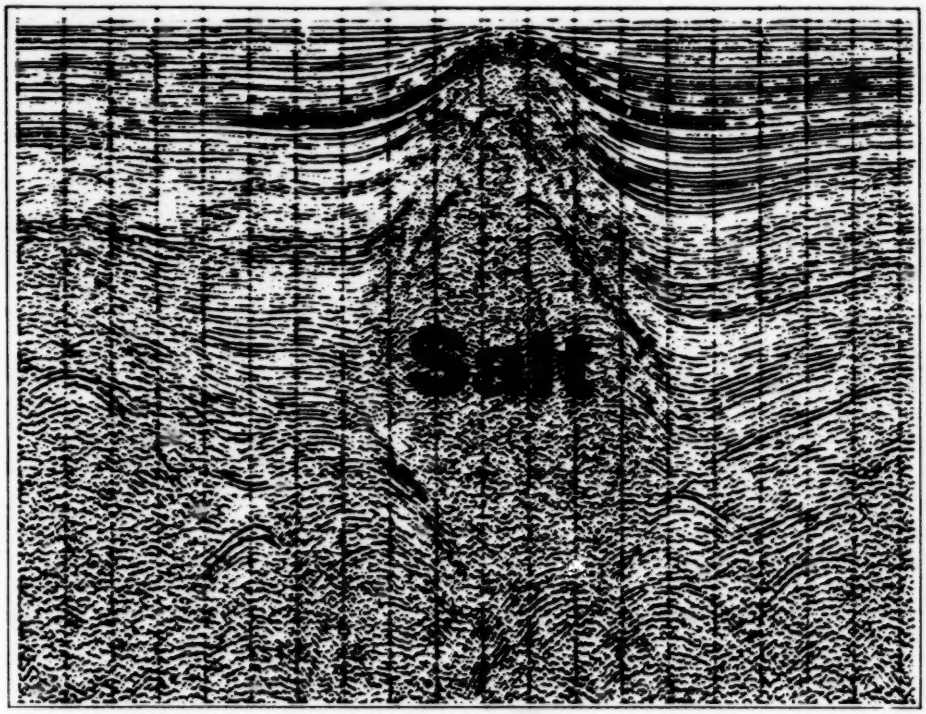


Figure 13. Seismic profile showing salt piercement structure

Seismic is based on a simple principle. An acoustic wave is initiated at the surface and the elapsed time of echoes from the various reflecting rock strata at depth is recorded. The longer the time from impulse to return of the reflection, the deeper the particular bed lies below the surface. Thus, a tilted (dipping) bed will give an increased time of reflection as the recorder moves from where a bed is shallow to where it is deeper. Intermittent recordings obtained along a line are processed into a continuous profile which gives a graphic portrayal of those beds that generate reflections of the acoustic wave (Figure 13). One method of creating seismic waves involves a vibrator truck that creates shock waves that penetrate the earth's crust (Figure 14).

In a general sense, the profile shows the rock layers and their deformation by folding, faulting or piercement by salt or shale intrusions. By using a grid or network of such profiles and by following a specific reflection, a contour map of subsurface structure is constructed — much as a topographic map of the earth is made. (The topographic hills and ridges of the surface map are similar to domes and anticlines in the subsurface while the valleys are similar to the synclines. A sharp cliff or locally steep slope is akin to a fault.)

Such maps indicate structural domes, anticlines, faults, and other features that could form traps for hydrocarbons. The actual depths at which these maps are made may vary from 100 m to more than 6000 m below the surface, depending on the thickness and the acoustical "transparency" of the column of sedimentary rocks and the estimated depth to potential oil or gas bearing formations.

It is, of course, necessary to know the surface positions from which all the recordings are made so the locations of possible drill sites can be relocated with accuracy. This is done on the recording boat by radio positioning from known stations on shore or by using the earth satellites as they traverse overhead.

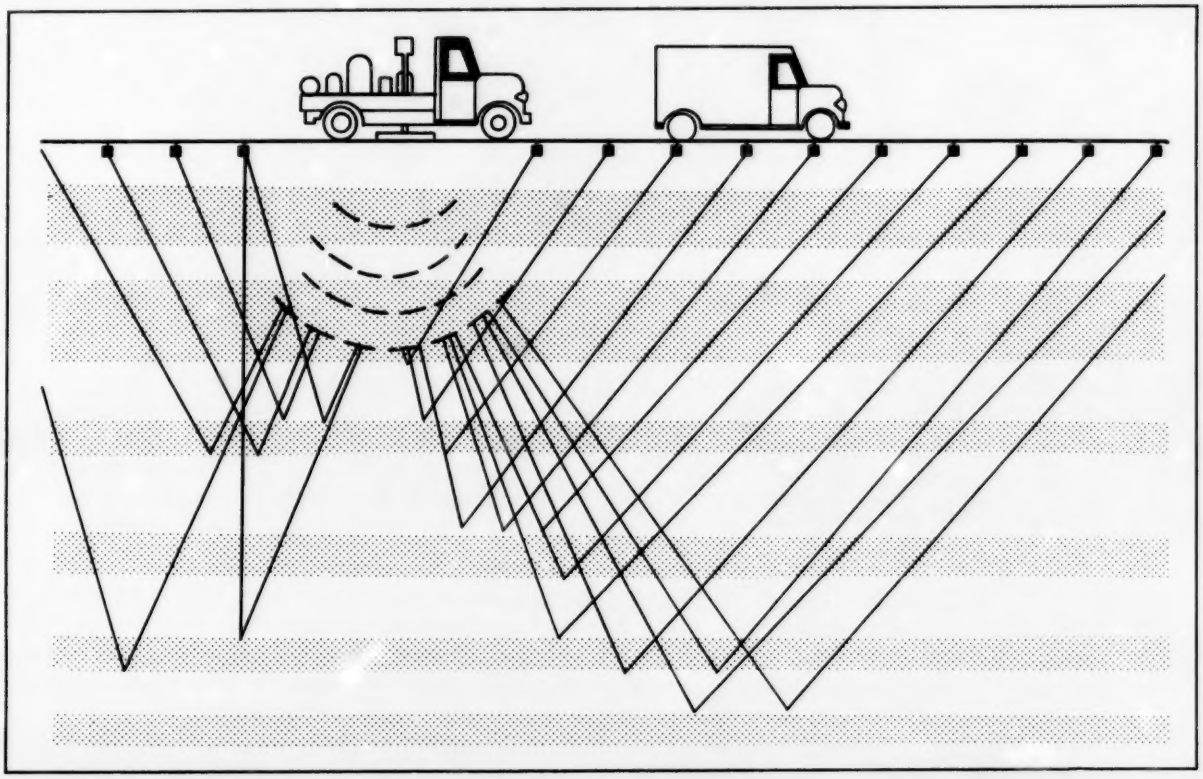
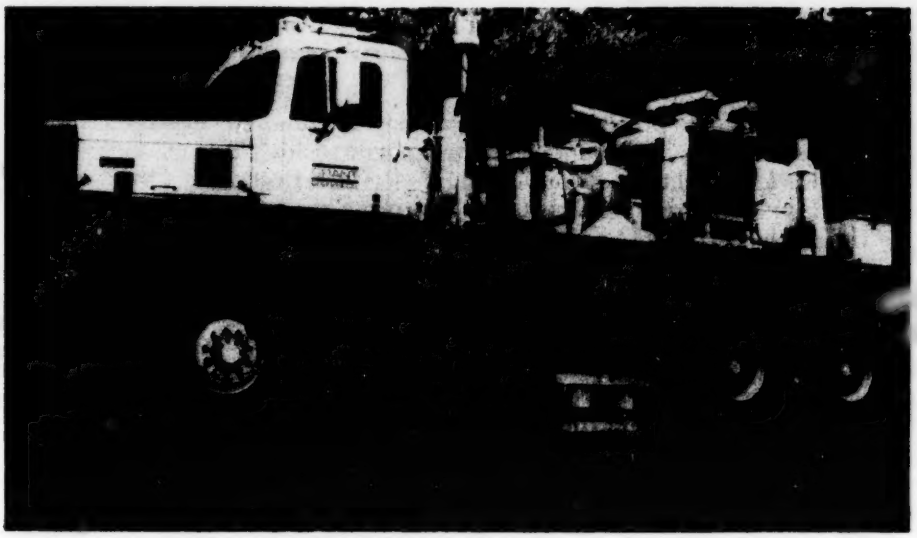


Figure 14. Schematic representation of shock waves created by vibrator truck, reflected on lithology and recorded, creating seismic profile



Vibrator truck recently used throughout the province

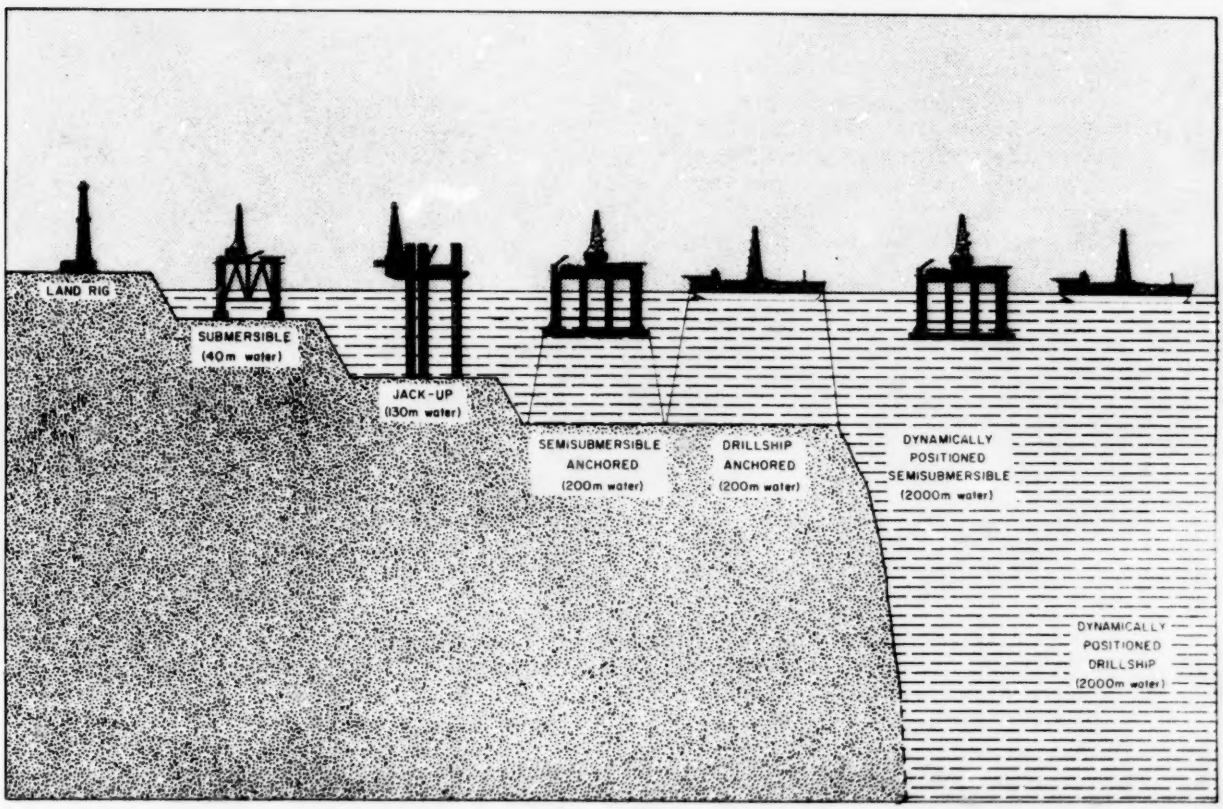
3. Drilling and Development

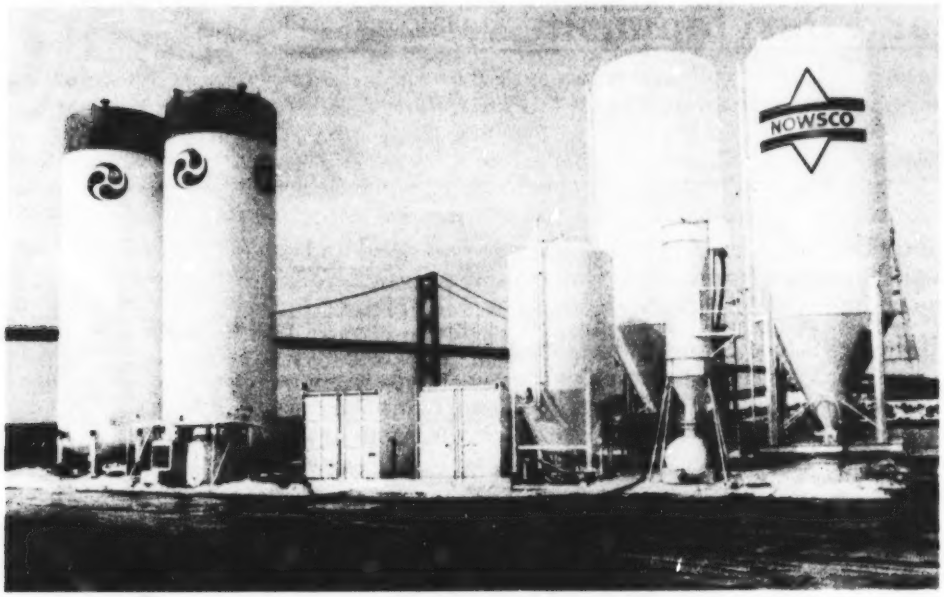
Once a drilling location is determined by geologists, geophysicists and management, a drilling contractor is found with equipment suitable for the particular water conditions and proposed depth of the hole (Figure 15).

If the well is located in relatively shallow water, a jack-up drilling rig may be used. This vessel is floated to the site, and its legs lowered so that it sits on the seafloor and only its drilling deck and equipment are above the waves. Because it actually sits on the seafloor, the depth in which it can be used is limited.

In deeper waters, the drilling contractor must turn to drill ships or semi-submersible drilling barges. Drill ships are exactly that — ships which house a drilling rig on their deck. The ship reaches the site, is anchored in position, and carries out its drilling duties through its hull. A semi-submersible drilling barge displaces as much as 50 000 tonnes of water and may equal a battleship in weight. To operate, it is moved into position and

Figure 15. Different types of drilling units





Oilfield bulk mud and cement storage and transfer equipment.

held in place by anchors or by computer controlled thrusters. The hull is then submerged so that part of the vessel sinks below the surface while the drilling deck remains above water. Since only a few columns emerge above the water line, the impact of hostile winds and waves is minimized.

Once the drilling vessel is in position, operations can begin. After a conductor pipe, 66-76 cm in diameter, is driven 30-100 m into the seafloor and cemented, drilling begins. The drill bit cuts a hole about 55 cm in diameter and between 300-600 m deep. A pipe is lowered into the hole and cement is forced between it and the wall of the hole. This is called casing. A blowout preventer stack is installed to contain accumulations of gas or oil that may be encountered in further drilling. More casing of smaller diameter may be cemented into place as the hole is deepened.

Now, drilling mud becomes of utmost importance. This special mixture of clay, water and chemical additives circulates through the drill pipe and cools and lubricates the rotating bit. The mud flows through the drill bit to wash cuttings back to the surface (providing information about the various formations being cut), to cool the bit as it rotates, and to hold the pressure against the various formations. The presence of oil and gas can be detected by analyzing the returning mud at the surface.

During the drilling operation, core samples may be taken to obtain information on the exact nature of the stratigraphy which has been penetrated. This is done in one of two ways. As the hole is being drilled, a special bit may be attached to the drill pipe and lowered into the hole and a core cut and collected in a cylinder. Or projectiles may be fired into the wall of the hole at certain depths, penetrating the formation and collecting a small core. The latter method can be used after drilling is completed and downhole log surveys have been made. In zones where favourable conditions are indicated by the logs, drill stem tests may be conducted. These tests allow fluids to ascend from the zones to the surface so samples can be taken and the pressure and flow rates monitored.

If it is determined that the potential of this discovery well could provide enough money to pay for further development plus yield a profit, engineering tests begin.

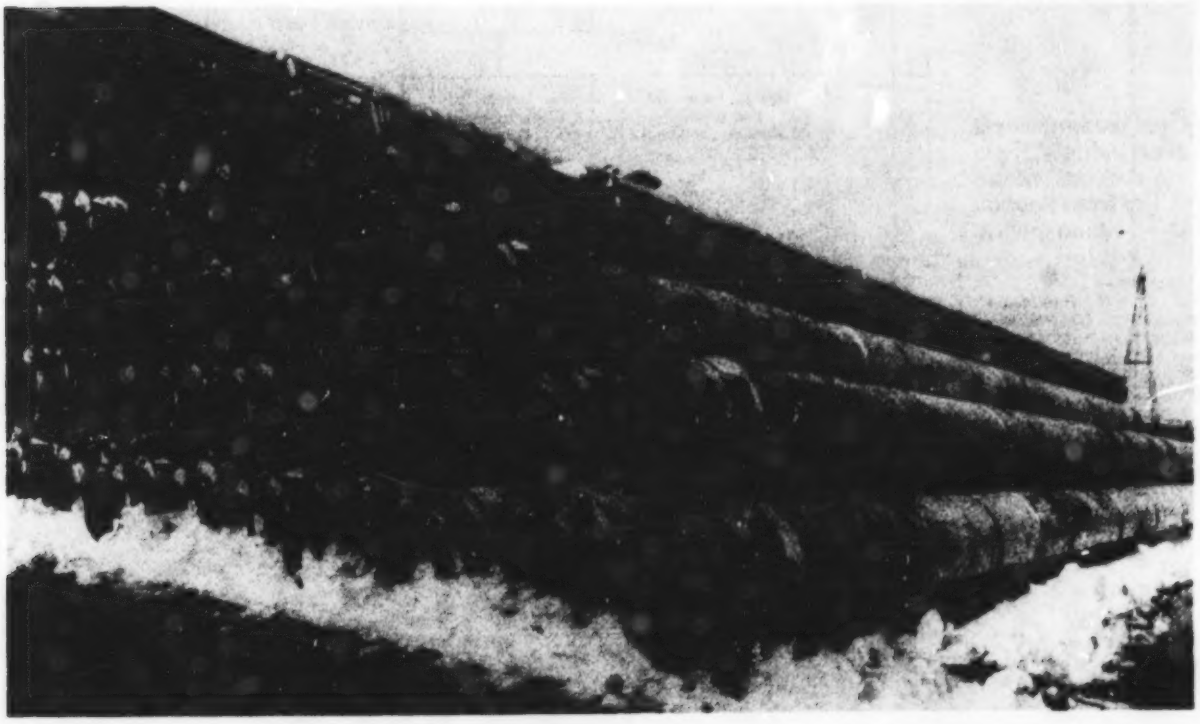
Production casing is inserted into the hole at a later stage. This casing prevents the hole from caving in, controls the flow of fluids between formations, confines the production to the specific area indicated to contain hydrocarbons, and permits the installation of equipment necessary for production.

The drilling contractor then drills a series of appraisal wells to delineate the field. With the data from the drill stem tests, downhole logs and samples combined with the geological and geophysical maps, the determination of the extent of the producing area, the calculation of the volume of oil and gas, an estimate of producible reserves can finally be made.

Studies are then made to determine the number of producing wells to be drilled, their spacing, the number and locations of producing platforms to be installed, and how the product is to be stored and transported to shore.

Exploratory drilling continues even after the development of a field has begun and is carried on for many years simultaneously with development work (Figure 16).

"Riser Pipe" used by floating drilling rigs. These pipes, when connected between the rig and the ocean floor, act as a guide for drilling tools and provide for drilling fluid returns.



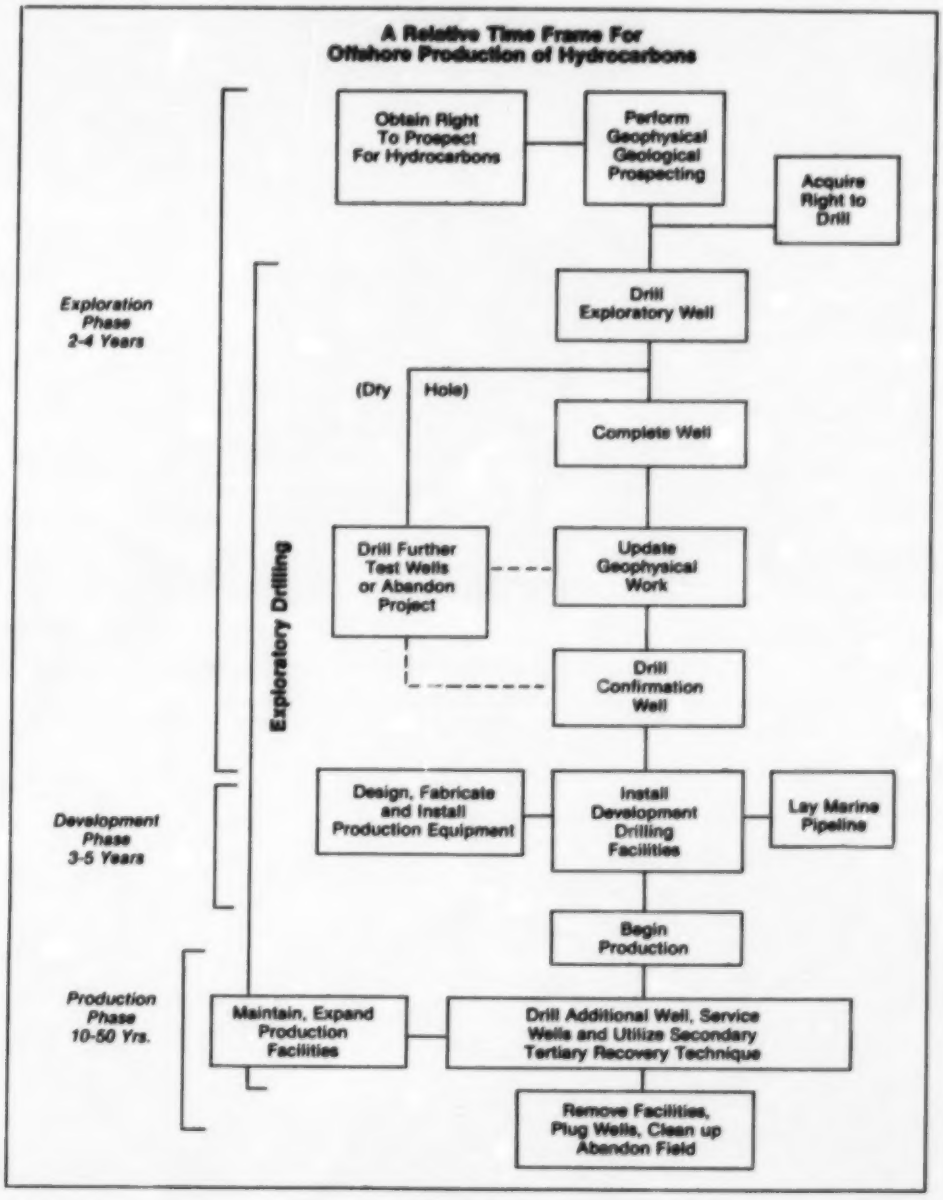

A Relative Time Frame For
Offshore Production of Hydrocarbons
Obtain Right To Prospect For Hydrocarbons
Perform Geophysical Geological Prospecting
Acquire Right to Drill
Drill Exploratory Well
(Dry Hole)
Complete Well
Drill Further Test Wells or Abandon Project
Update Geophysical Work
Drill Confirmation Well
Design, Fabricate and Install Production Equipment
Install Development Drilling Facilities
Lay Marine Pipeline
Begin Production
Maintain, Expand Production Facilities
Drill Additional Well, Service Wells and Utilize Secondary Tertiary Recovery Technique
Remove Facilities, Plug Wells, Clean up Abandon Field
Exploration Phase 2-4 Years
Development Phase 3-5 Years
Production Phase 10-50 Yrs.
Exploratory Drilling

Figure 16.
A relative time frame for offshore production of hydrocarbons

Notes

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6. R.D. Howie, M.S. Barss, **Offshore Geology of Eastern Canada,** G.S.C. Paper 74-30, Vol. 2, 1975, p. 48.
7. Howie, Barss, **Offshore Geology,** p. 35-48.
8. Bell, **Possibilities for Occurrence,** p. 22.

Barite processing plant, Walton, Nova Scotia. Barite is a mineral used in drilling mud.

APPENDICES

Data on recent and current wells are subject to minor change.

Abbreviations

RT	— Rotary Table
KB	— Kelly Bushing
GL	— Ground Level
P & A	— Plugged and Abandoned
P & S	— Plugged and Suspended
TD	— Total Depth

Well Symbols

— Drilling

— Plugged and Abandoned

— Significant Gas

— Gas Show

— Significant Oil

— Oil Show

— Significant Oil and Gas

— Oil and Gas Show

Appendix I

Wells Drilled Offshore Nova Scotia

Well Name	Latitude Longitude	Drilling Unit	Spud Date Rig Released	RT Elev'n Water Depth (m)	Depth in m (RT) Well Status
Mobil Sable Island C-67	43° 56′ 04.9″ 59° 55′ 01.4″	Bawden Rig 18	67-06-07 68-01-02	8.2 KB 3.9 GL	4 604.3 P & A
Shell Onondaga E-84	43° 43′ 16.14″ 60° 13′ 17.41″	Sedneth 1	69-09-01 69-11-11	25.9 57.9	3 988.3 P & A
Shell Oneida O-25	43° 14′ 57.36″ 61° 33′ 36.49″	Sedneth 1	69-11-16 70-02-10	25.9 82.3	4 119.9 P & A
Shell Naskapi N-30	43° 29′ 46.78″ 62° 33′ 59.54″	Sedneth 1	70-02-16 70-03-19	26 95.1	2 205.2 P & A
Shell Mohawk B-93	42° 42′ 10.52″ 64° 43′ 53.50″	Sedco H	70-05-03 70-05-23	31.4 117	2 126 P & A
Shell Mic Mac J-77	44° 36′ 42.81″ 50° 26′ 10.86″	Sedneth 1	70-03-25 70-05-24	26 62.8	3 886.2 P & A
Shell Abenaki L-57	44° 16′ 34.49″ 59° 53′ 39.64″	Sedco H	70-05-28 70-07-06	31.4 108.8	2 178.4 P & A
Shell Missisauga H-54	44° 23′ 20.39″ 59° 22′ 47.56″	Sedneth 1	70-05-26 70-07-20	25.9 102.1	4 202.3 P & A
Shell Onondaga O-95	43° 44′ 48.09″ 60° 13′ 52.60″	Sedco H	70-07-09 70-08-16	31.4 53.9	3 314.4 P & A
Shell Huron P-96	44° 35′ 47.10″ 58° 28′ 50.63″	Sedneth 1	70-07-22 70-08-27	25.9 57.9	3 018.4 P & A
Shell Iroquois J-17	44° 26′ 31.37″ 59° 47′ 12.28″	Sedco H	70-08-18 70-09-06	31.4 59.4	2 086.4 P & A
Shell Cree E-35	43° 44′ 20.70″ 60° 35′ 55.89″	Sedco H	70-09-08 70-11-03	31.4 53.3	3 983.7 P & A
Shell Mic Mac H-86	44° 35′ 27.71″ 59° 27′ 03.12″	Sedneth 1	70-08-31 70-12-02	25.9 54.3	4 785.4 P & A
Shell Wyandot E-53	44° 52′ 20.70″ 59° 23′ 54.05″	Sedco H	70-11-07 70-12-14	31.4 121	3 049.5 P & A
Shell Argo F-38	45° 27′ 23.22″ 58° 50′ 24.34″	Sedco H	70-12-17 71-02-19	31.4 71.6	3 386.3 P & A
Shell Fox I-22	45° 21′ 33.60″ 59° 33′ 16.00″	Sedco H	71-02-20 71-03-03	31.4 83.8	829.7 P & A
Shell Abenaki J-56	44° 15′ 44.95″ 59° 53′ 03.22″	Sedneth 1	70-12-04 71-03-13	25.9 106.7	4 569.3 P & A
Shell Erie D-26	44° 55′ 03.52″ 59° 34′ 29.82″	Sedneth 1	71-03-16 71-04-11	25.9 98.1	2 375.9 P & A
Mobil-Tetco Esperanto K-78	44° 47′ 31.26″ 59° 11′ 19.24″	Sedco H	71-03-09 71-04-24	31.4 68.6	3 540.3 P & A
Shell Crow F-52	45° 21′ 24.23″ 59° 08′ 22.73″	Sedneth 1	71-04-12 71-04-27	25.9 94.5	1 506.6 P & A
Shell Sauk A-57	44° 16′ 05.70″ 58° 37′ 44.41″	Sedneth 1	71-04-30 71-07-10	25.9 60	4 575 P & A
Mobil-Tetco Dauntless D-35	44° 44′ 08.26″ 57° 20′ 46.62″	Sedco H	71-04-26 71-07-16	31.4 69.2	4 741.2 P & A
Shell Chippewa L-75	44° 34′ 35.87″ 58° 41′ 50.54″	Sedneth1	71-07-12 71-08-02	24.7 67.7	2 125.9 P & A

Well Name	Latitude Longitude	Drilling Unit	Spud Date Rig Released	RT Elev'n Water Depth (m)	Depth in m (RT) Well Status	
Shell Onondaga F-75	43° 44′ 17.84″ 60° 11′ 36.25″	Sedco H	71-07-28 71-09-07	31.4 56.4	3 890.8 P & A	✣
Shell Triumph P-50	43° 39′ 51.62″ 59° 51′ 02.36″	Sedneth I	71-08-04 71-10-10	25.9 90.2	4 595.4 P & A	✣
tMobil-Tetco Sable Island E-48	43° 57′ 20.35″ 60° 07′ 24.44″	Bawden Rig 14	71-05-28 71-10-15	6.4 0	3 602.7 P & A	✸
Shell Eurydice P-36	45° 25′ 47.30″ 60° 04′ 46.97″	Sedco H	71-09-15 71-10-24	29.9 164.6	2 965.1 P & A	✣
Shell Chippewa G-67	44° 36′ 20.50″ 58° 39′ 44.62″	Sedco H	71-10-28 71-12-18	29.9 70.1	3 669.8 P & A	✣
Shell Mohican I-100	42° 59′ 39.04″ 68° 28′ 51.32″	Sedco H	71-12-27 72-03-10	29.9 153.3	4 393.4 P & A	✣
Shell Marmora C-34	43° 43′ 13.79″ 60° 05′ 21.93″	Sedneth I	72-01-15 72-03-31	25.9 57.6	4 037.9 P & A	✣
Shell Primrose N-50	43° 59′ 48.43″ 59° 06′ 51.63″	Sedco H	72-03-14 72-04-21	29.9 90.8	1 713.6 P & A	✸
Mobil-Tetco Sable Island O-47	43° 56′ 56.70″ 60° 06′ 38.08″	Bawden Rig 14	71-12-13 72-07-01	7 KB 1.8 GL	4 198.6 P & S	✣
Shell-Mobil- Tetco Eagle D-21	43° 50′ 06.73″ 59° 34′ 09.21″	Sedco H	72-04-22 72-07-02	29.9 51.2	4 660.4 P & A	✣
Mobil-Tetco Sable Island I-H-58	43° 57′ 27″ 60° 07′ 37″	Bawden Rig 9	72-06-03 72-08-27	10.7 KB 1.8 GL	3 039.2 P & S	✸
Mobil-Tetco- Thebaud P-84	43° 53′ 59.53″ 60° 12′ 19.34″	Sedco H	72-07-08 72-10-13	28.6 25.9	4 114.8	✣
Mobil-Tetco Sable Island 2-H-58	43° 57′ 27.14″ 60° 07′ 37.73″	Bawden Rig 9	72-10-06 72-12-31	10.6 KB 1.8 GL	2 758.4 P & S	✸
Shell Primrose A-41	44° 00′ 05.68″ 59° 06′ 18.26″	Sedco H	72-10-15 73-01-27	29.9 109.7	3 616.5 P & A	✣
Shell Primrose F-41	44° 00′ 29.55″ 59° 07′ 06.52″	Sedco H	73-01-30 73-03-05	29.9 68.6	2 592.3 P & A	✣
Mobil-Tetco Sable Island 3-H-58	43° 57′ 27.2″ 60° 07′ 37.8″	Bawden Rig 9	73-01-01 73-03-21	10.6 KB 1.8 GL	3 739.9 P & S	✸
Shell Marmora P-35	43° 44′ 59.36″ 60° 04′ 47.58″	Sedco H	73-03-06 73-04-21	29.9 53.3	4 092.9 P & A	✣
Mobil-Tetco Bluenose G-47	44° 06′ 20.79″ 59° 21′ 27.35″	Sedco J	73-01-25 73-04-25	29.9 81.4	4 587.2 P & A	✣
Shell Tuscarora D-61	44° 40′ 10.35″ 58° 55′ 10.85″	Sedco H	73-04-23 73-06-02	29.9 78.9	3 939.5 P & A	✣
Mobil-Tetco Cohasset D-42	43° 51′ 06.52″ 60° 37′ 13.89″	Sedco J	73-04-27 73-07-16	31.4 41.1	4 427.2 P & S	●
Mobil-Tetco Sable Island 4-H-58	43° 57′ 27.2″ 60° 07′ 37.8″	Bawden Rig 9	73-03-22 73-08-11	10.6 KB 1.8 GL	4 519.3 P & S	✸
Shell Amoco Cap Rouge F-52	47° 11′ 20.29″ 61° 08′ 15.32″	Sedco II	73-06-08 73-09-03	31.1 56.7	4 932.3 P & A	✣
Mobil-Tetco Sable Island 5-H-58	43° 57′ 27.2″ 60° 57′ 37.8″	Bawden Rig 9	73-08-15 73-09-18	10.6 KB 1.8 GL	2 478 P & A	✸

Well Name	Latitude Longitude	Drilling Unit	Spud Date Rig Released	RT Elev'n Water Depth	Depth (RT) Well Status	
Mobil-Tetco Sable Island 6-H-58	43° 57' 27.2" 60° 07' 37.8"	Bawden Rig 9	73-09-22 73-10-18	10.6 KB 1.8 GL	2 355.2 P & A	
Union et al Shell Ojibwa E-07	43° 46' 20.44" 61° 46' 14.42"	Sedco H	74-02-04 74-02-28	29.9 75.6	2 329.6 P & A	
Mobil-Tetco-Texaco Citnalta I-59	44° 08' 42.58" 59° 37' 32.11"	Sedco J	74-02-04 74-04-29	29.9 94.5	4 575 P &S	
Shell Demascota G-32	43° 41' 27.2" 60° 49' 54.00"	Sedco H	74-03-01 74-05-20	29.9 54.3	4 672.3 P & A	
Union et al Sambro I-29	43° 38' 35.04" 62° 48' 17.04"	Sedco H	74-05-23 74-06-27	29.9 193.5	3 069.6 P & A	
Union et al Jason C-20	45° 29' 05.45" 58° 32' 28.27"	Sedco H	74-07-03 74-07-22	29.9 112.8	2 482.9 P & A	
Union et al Hercules G-15	45° 34' 20.65" 58° 47' 13.06"	Sedco H	74-07-23 74-08-01	29.9 115.8	1 081.1 P & A	
Texaco-Shell Intrepid L-80	43° 49' 35.78" 59° 56' 43.82"	Sedco J	74-05-18 74-08-15	31.4 43.6	4 162 P & A	
Murphy et al North Sydney P-05	46° 34' 46.24" 59° 45' 01.65"	Sedco H	74-08-10 74-09-07	29.9 62.8	1 660.9 P & A	
Union et al Montagnais I-94	42° 53' 40.71" 64° 13' 46.51"	Sedco H	74-09-12 74-09-29	29.9 112.8	1 645.9 P & A	
Mobil-Tetco-Gulf Adventure F-80	45° 19' 27.54" 57° 56' 22.80"	Sedco J	75-01-13 75-02-22	29.9 98.8	1 999.2 P & A	
Mobil-Texaco Sachem D-76	44° 35' 09.22" 57° 41' 58.29"	Sedco J	75-05-17 75-07-30	29.9 58.5	4 878.6 P & A	
Shell Onondaga B-96	43° 45' 08.23" 60° 14' 09.63"	Sedco H	76-01-12 76-03-21	29.9 60.4	3 757.6 P & A	
Petro-Canada Shell Mic Mac D-89	44° 38' 08.86" 59° 28' 18.93"	Sedco H	76-03-26 76-05-04	29.9 85.3	3 216.4 P & A	
Petro-Canada Mobil Hesper I-52	44° 41' 40.33" 57° 52' 32.24"	Sedco H	76-05-08 76-06-05	29.9 42.1	2 804.2 P & A	
Shell et al North Sydney F-24	46° 33' 23.12" 59° 48' 45.47"	Sedco H	76-06-09 76-06-14	29.9 59.7	1 706.8 P & A	
Petro-Canada-Shell Penobscot L-30	44° 09' 43.55" 60° 04' 09.33"	Sedco H	76-07-18 76-09-23	29.9 137.5	4 267.2 P & A	
Petro-Canada-Shell Wenonah J-75	43° 34' 34.43" 60° 26' 13.72"	Sedco H	76-09-26 76-11-15	29.9 66.7	3 669.8 P & A	
Petro-Canada-Shell Moheida P-15	43° 04' 56.31" 62° 16' 44.32"	Sedco H	76-11-18 77-02-15	29.9 111.9	4 297.7 P & A	
Shell-Petro-Canada Penobscot B-41	44° 10' 02.44" 60° 06' 34.50"	Sedco H	77-02-18 77-03-30	29.9 117.9	3 444.2 P & A	
Mobil-Tetco-PEX Migrant N-20	43° 59' 56.24" 60° 17' 18.23"	Gulftide	77-07-29 78-01-23	26.1 13.7	4 668.7 P & A	
Mobil-Tetco PEX Thebaud I-94	43° 53' 43.67" 60° 13' 38.13"	Gulftide	78-02-26 78-06-03	29.9 28	3 962.4 P & A	
Chevron PEX Shell Acadia K-62	42° 51' 42.54" 61° 55' 00.21"	Ben Ocean Lancer	78-04-11 78-08-02	12.8 866.2	5 286.1 P & A	

Well Name	Latitude Longitude	Drilling Unit	Spud Date Rig Released	RT Elev'n Water Depth	Depth (RT) Well Status	
Mobil-Tetco PEX Cohasset P-42	43° 51' 48.23" 60° 36' 16.62"	Gulftide	78-06-09 78-07-10	30.5 34.1	2 590.8 P & A	✛
Mobil-Tetco PEX C-Cohasset L-97	43° 56' 37.19" 60° 29' 58.55"	Gulftide	78-07-13 78-11-13	30.5 21.6	4 871.9 P & A	✛
Mobil Texaco PEX Venture D-23	44° 02' 15" 59° 34' 21"	Gulftide	78-11-28 79-06-16	31.7 20.1	4 945 P & S	✲
Mobil et al Venture B-13	44° 02' 11.61" 59° 32' 03.54"	Rowan Juneau	80-08-17 81-06-06	33.8 24.7	5 212 P & S	✲
Mobil et al Venture B-43	44° 01' 45.01" 59° 37' 21.03"	Rowan Juneau	81-07-06 82-04-25	33.8 20.4	5 872 P & S	✲
Petro-Canada et al Banquereau C-21	44° 01' 07.52" 58° 34' 00.24"	Bow Drill 1	81-12-02 82-08-01	27.0 83.0	4 991 P & S	✲
Mobil et al Olympia A-12	44° 01' 03.27" 59° 46' 44.09"	Zapata Scotian	82-04-23 83-01-10	38.1 39.9	6 064 P & S	✲
Mobil et al South Venture O-59	43° 58' 52.83" 59° 38' 08.49"	Rowan Juneau	82-04-29 83-01-02	35.4 24.4	6 176 P & S	✲
Petro-Canada et al Banquereau I-13	44° 12' 33.16" 58° 31' 49.38"	Bow Drill 1	82-08-02 82-12-27	27.0 97.3	5 188 P & A	✛
Petro-Canada et al West Esperanto B-78	44° 47' 03.40" 58° 26' 11.22"	SDS Vinland	82-08-22 83-05-05	23.3 91.1	5 703 P & A	✛
Shell et al Shubenacadie H-100	42° 49' 28.43" 61° 28' 42.81"	Sedco 709	82-11-05 83-02-12	24.1 1 475.0	4 200 P & A	✛
Mobil et al Bluenose 2G-47	44° 06' 22.30" 59° 21' 23.05"	John Shaw	82-12-30	24.4 85.3	5 797 Testing	
Mobil et al Venture B-52	44° 01' 12.88" 59° 38' 07.76"	Rowan Juneau	83-01-19	34.0 19.5	5 960 Testing	
Mobil et al Arcadia J-16	44° 05' 43.58" 59° 31' 58.19"	Zapata Scotian	83-01-27 83-07-19	38.1 55.5	6 005 P & S	✲
Petro-Canada et al S.W. Banquereau F-34	44° 03' 15.63" 58° 50' 21.60"	Bow Drill 1	83-02-20	24.9 113.7	6309 Testing	
Shell/Petro-Can et al Glenelg J-48	43° 37' 39.00" 60° 06' 25.44"	Sedco 709	83-02-22	24.0 83.7	Drilling	
Shell/Petro-Can et al Uniacke G-72	44° 11' 29.17" 59° 41' 09.75"	SDS Vinland	83-05-09	23.5 152.9	Drilling	
Mobil et al Venture H-22	44°01'24.10" 59°33'06.10"	Zapata Scotian	83-07-26	38.1 24.0	Drilling	
Husky/Bow Valley et al Glooscap C-63	43°12'09.85" 62°09'56.73"	Bow Drill II	83-08-07	22.9 99.0	Drilling	

Appendix II

Exploratory Holes With Petroleum Significance Drilled Onshore Over the Past 25 Years

Well Name	Latitude Longitude	Company (Operator)	Spud Date Rig Release	Depth in m (KB)* Well Status [1]
Lura #1 (NSDM #2671)	45° 39′ 42″ N 61° 50′ 50″ W	Lura Oil & Gas Exploration	58-10-04 58-12-12	607
Inverness #1	46° 03′ 56″ N 61° 23′ 42″ W	Imperial Oil Limited	[2]	155
Inverness #2	46° 02′ 09″ N 61° 22′ 40″ W	Imperial Oil Limited	[2]	79 (oil show)
Inverness #3	46° 06′ 42″ N 61° 11′ 37″ W	Imperial Oil Limited	[2]	145.9 (oil show)
Inverness #4	45° 55′ 32″ N 61° 27′ 21″ W	Imperial Oil Limited	[2]	143.8
Inverness #5	46° 05′ 10″ N 61° 09′ 46″ W	Imperial Oil Limited	[2]	30.4 (oil show)
Inverness #6	46° 05′ 01″ N 61° 09′ 33″ W	Imperial Oil Limited	[2]	51.7
Mabou #1	46° 01′ 30″ N 61° 24′ 03″ W	Imperial Oil Limited	59-10-24 59-12-31	1 568
Port Hood #1	46° 01′ 55″ N 61° 29′ 00″ W	Imperial Oil Limited	60-01-16 60-04-11	3 000
Pacific Fox Harbour C-96-V	45° 50′ 56″ N 63° 30′ 47″ W	Pacific Petroleum	63-12-10 64-05-04	3 003
Murphy et al Birch Grove #1	46° 08′ 42″ N 59° 56′ 05″ W	Murphy Oil Company Limited	68-02-08 68-05-20	1 344
Anschutz-Wallace Station #1	34° 46′ 15″ N 63° 30′ 30″ W	Anschutz Corporation	72-12-22 73-08-29	4 536
Gulf Hastings	45° 49′ 00″ N 64° 05′ 30″ W	Gulf Oil Canada Limited	75-06-11 75-08-07	2 939.5
Soquip Acc. et al Noel #1	45° 12′ 33″ N 63° 42′ 28″ W	Soquip. Acc. et al	75-07-19 75-08-13	1 447.8
Bras d'Or Anschutz #1	45° 39′ 40″ N 61° 52′ 30″ W	Anschutz Corporation	76-07-27 76-08-12	1 044.8
Chevron-Irving Bras d'Or #1	45° 52′ 30″ N 61° 00′ 20″ W	Chevron Standard Limited	79-09-21 79-09-30	216
Chevron-Irving Bras d'Or #2	45° 52′ 45″ N 61° 00′ 05″ W	Chevron Standard Limited	79-10-10 79-12-15	375
Chevron-Irving Malagawatch #1	45° 52′ 05″ N 60° 55′ 18″ W	Chevron Standard Limited	79-10-31 79-11-23	948 oil show
Chevron-Irving Malagawatch #2	45° 52′ 05″ N 60° 55′ 18″ W	Chevron Standard Limited	79-12-10 80-01-11	611 oil show
Chevron-Irving Scotsburn #2	43° 38′ 21″ N 63° 00′ 10″ W	Chevron Standard Limited	81-08-11 81-11-23	2 593

[1] All P & A
[2] All six holes drilled between 58-08-26 and 58-09-10

POOR

QUALITY

ORIGINAL